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Air Mass Computer Program for Atmospheric Transmittance/Radiance Calculation: FSCATM

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9 March 1983

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OPTICAL PHYSICS DIVISION

PROJECT 7670

AIR FORCE GEOPHYSICS LABORATORY

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1. It calculates the layer-by-layer integrated absorber amounts and density-weighted pressure and temperature for an arbitrary slant path through the atmosphere.
2. It assumes a spherically symmetric atmosphere with exponential profiles of density and refractivity between layer boundaries.
3. It allows a variety of options for specifying the slant path.
4. It includes six representative atmospheric profiles of pressure and temperature, and of density for the gases H_2O , CO_2 , O_3 , N_2O , CO , CH_4 , and O_2 and has provision for user-supplied profiles of up to 20 gases.
5. The output layering may either be generated internally or supplied by the user.
6. It is portable to 32 bit word computers in single precision and compatible with both ANSI Standard FORTRAN 66 and 77.
7. It is modular and easily modified to suit the users' particular needs. A discussion of atmospheric profile data and a survey of the literature are included in appendices.



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Air Mass Computer Program for Atmospheric Transmittance/Radiance Calculation: FSCATM

1. INTRODUCTION

Calculations of atmospheric transmittance and radiance require knowledge of the amount and distribution of the absorbing gases along the optical path. The integrated amount of gas along a path compared to the amount for a vertical path from ground to space is generally referred to as "air mass". Under some circumstances, air mass can be calculated simply by assuming a plane parallel atmosphere and using the secant approximation. For other cases, for example, large zenith angles or tangent paths, curvature and refraction must be taken into account, requiring a more elaborate integration along the path.

This report presents the Fortran program FSCATM, which calculates the integrated absorber amounts for an arbitrary slant path through the atmosphere, including the effects of both curvature and refraction. FSCATM is specifically designed to create the atmosphere inputs to the AFGL line-by-line atmospheric transmittance and radiance program FASCOD¹, but the program is general enough to be useful to others working in the field of infrared radiative transfer in the atmosphere.

(Received for publication 1 March 1983)

1. Clough, S.A., Kneizys, F.X., Rothman, L.S., and Gallery, W.O. (1981) Atmospheric spectral transmittances and radiance: FASCOD1B, SPIE, Atmospheric Transmission 277:152-166.

Among the features of FSCATM are:

1. It calculates the layer-by-layer integrated absorber amounts and density-weighted pressure and temperature for an arbitrary slant path through the atmosphere,
2. It assumes a spherically symmetric atmosphere with exponential profiles of density and refractivity between layer boundaries,
3. It allows a variety of options for specifying the slant path,
4. It includes six representative atmospheric profiles of pressure and temperature, and of density for the gases H_2O , CO_2 , O_3 , N_2O , CO , CH_3 and O_2 , and has provision for user-supplied profiles of up to 20 gases,
5. The output layering may either be generated internally or supplied by the user,
6. It is portable to 32 bit word computers in single precision and compatible with both ANSI Standard FORTRAN 66 and 77, and
7. It is modular and easily modified to suit the users' particular needs.

As distributed FSCATM is a subroutine called by FASCODE. However, it may very easily be converted to a self-contained program (see Section 3.4 for details). References to FSCATM in this report will assume that it is being run in the stand-alone mode. FSCATM is available as part of the FASCOD1C package (see Section 3.5 for details).

Section 2 of this report provides background on the calculation of air mass, including atmospheric refraction, the numerical algorithm used here, and some examples of the effects of curvature and refraction on air mass. Section 3 documents the program FSCATM, including usage and sample input and output.

Appendix A discusses the six standard atmospheric profiles included in FSCATM and describes other sources of atmospheric profile data. Appendix B describes the formula for the index of refraction of air used in FSCATM. Finally, Appendix C gives a brief survey of the literature on air-mass calculation and atmospheric refraction.

2. AIR MASS

2.1 Definitions

The integrated absorber amount, n , along a slant path through the atmosphere is given by

$$m = \int \rho ds \quad , \quad (1)$$

where ρ is the mass or number density of the gas and ds is the element of length along the path (m is also sometimes referred to as the "column density"). For vertical path from ground to space for the U.S. Standard Atmosphere 1962, m for the total air density is 2.15×10^{25} molecules $\text{cm}^{-2} = m_0$. This quantity m_0 is sometimes referred to as "one air mass". The term air mass is somewhat ambiguous; in this report the term air mass for a particular path will refer to the relative air mass or m/m_0 . For example, the air mass for a path from ground to space, where the zenith angle at the ground is 90.0° , is 38.1. The term air mass applies specifically to total amount of air along the path. For non-uniformly mixed gases, such as H_2O or O_3 , the relative amount of gas along a slant path compared to a vertical path may differ greatly from the (total) air mass.

These calculations assume a spherically-symmetric layered atmosphere with the pressure, temperature, and absorbing gas densities defined at a suitable number of layer boundaries. For any path through the atmosphere, the integrated absorber amounts, m , are calculated individually for each layer and summed over the layers. This discussion will be confined to the calculation for a single layer.

Figure 1 illustrates the geometry of a path through a single layer. The layer is bounded by the radii r_1 and r_2 , α and ϕ are the zenith angles at r_1 and r_2 respectively, s is the curved path length, β is the earth centered angle, and ψ is the bending along the path. The radius of the earth is r_e while the radius to any point is r . The height z above the lower boundary equals $r - r_e$.

The pressure P , temperature T , and absorbing gas density ρ are given at r_1 and r_2 . Inside the layer, temperature is interpolated linearly, while pressure and density are assumed to follow an exponential distribution. For pressure,

$$P(z) = P_1 \exp [-z/H_p] \quad (2)$$

$$H_p = -(\Delta z) / \ln(P_2/P_1) \quad (3)$$

where H_p is called the pressure scale height and Δz is $r_2 - r_1$. Equation (2) is exact for an isothermal layer and is an excellent approximation for a non-isothermal layer if the layer is thin compared to a scale height.

Similarly, the density is given by:

$$\rho(z) = \rho_1 \exp [-z/H_\rho] \quad (4)$$

$$H_\rho = -\Delta z / \ln(\rho_2/\rho_1) \quad (5)$$

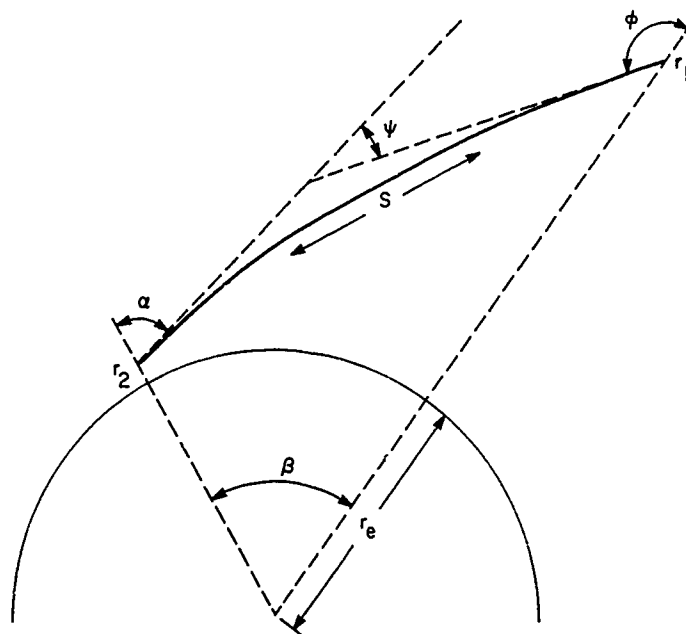


Figure 1. Geometry of the Refracted Path Through a Single Layer

For a uniformly mixed gas in an isothermal layer, Eq. (4) is again exact and for a non-isothermal layer is a good approximation. For a non-uniformly mixed gas, the density will not follow an exponential distribution. In such cases it is necessary to make the spacing between boundaries small enough so that the calculated density between layers does not depend significantly upon the particular interpolation scheme used.

The integrated amount m of the absorbing gas for the layer can be rewritten from Eq. (1) as

$$m = \int_1^2 \rho(z) \frac{ds}{dz} dz \quad (6)$$

From small zenith angles, ds/dz is essentially constant over the layer and equals $\sec \theta$, where θ is the incident angle of the path at z (see Figure 2). In this case, Eq. (6) can be approximated as:

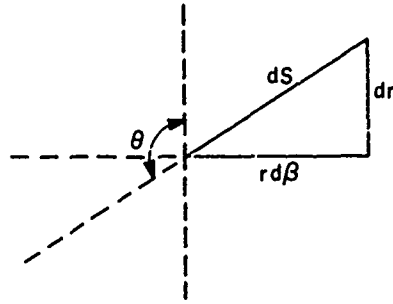


Figure 2. The Differential Path Quantities at a Point

$$m = \sec \theta \int_1^2 \rho \, dz \quad . \quad (7)$$

This approximation is the same as assuming a plane parallel atmosphere. The vertical integral of the density has a particularly simple analytic solution when the profile is exponential:

$$\int_1^2 \rho \, dz = H_\rho (\rho_1 - \rho_2) \quad . \quad (8)$$

For larger zenith angles where the earth's curvature is important but where refraction is still not significant, Eq. (6) can be solved analytically using the Chapman functions. (See Appendix C for references to the Chapman functions.) For even larger zenith angles, refraction must be taken into account. In this later case the layer can be divided into a number of sublayers bounded by z_1, z_2, \dots, z_J , which need not be uniformly spaced. The spacing between sublayers $\Delta z_j = z_{j+1} - z_j$ is determined by the requirement that the integral in Eq. (6) can be adequately represented by the sum over the sublayers j :

$$m = \sum_j \rho_j \frac{ds}{dz_j} \Delta z_j \quad . \quad (9)$$

where

$$\overline{\rho_j} = \frac{1}{\Delta z_j} \int_j^{j+1} \rho \, dz = \frac{1}{\Delta z_j} H_\rho (\rho(z_j) - \rho(z_{j+1})) \quad (10)$$

$$\overline{\frac{ds}{dz_j}} = \frac{1}{\Delta z_j} \int_j^{j+1} ds = \frac{\Delta s_j}{\Delta z_j} \quad (11)$$

$$\Delta z_j = z_{j+1} - z_j \quad (12)$$

The problem now is to determine the number and spacing of the sublayers and the path length Δs_j through each sublayer, including the effects of refraction. This problem is discussed in the next section.

In addition to the absorber amount, atmospheric transmittance calculations require an effective pressure and temperature for a layer. The effective pressure is required to calculate the halfwidth and the effective temperature is used to calculate the line intensity halfwidth, and, in emission, blackbody source function for a layer. The effective values are those that make the absorption and/or emission of an equivalent homogeneous layer equal to that of the non-homogeneous layer. There is no single definition of the effective pressure or temperature: the effective values depend upon many factors such as the path, the density distribution, and the spectral region, and will in general be different for different absorbing gases. The most generally applicable definition, however, is the density weighted average:

$$\overline{P} = \int P \rho^* ds / \int \rho^* ds \quad (13)$$

$$\overline{T} = \int T \rho^* ds / \int \rho^* ds \quad (14)$$

where ρ^* is the total air density. For a uniformly mixed gas with no temperature dependence in the line intensities, the mean pressure given by Eq. (13) is essentially the Curtis-Godson approximation.

The effective pressure \overline{P} and temperature \overline{T} are calculated in a way similar to the absorber amount in Eq. (9), using

$$\overline{Pm}^* = \int P \rho^* ds = \sum \frac{\overline{\Delta s}_i}{\Delta z_i} \int_i^{i+1} P(z) \rho^*(z) dz \quad (15)$$

$$\overline{Tm}^* = \int T \rho^* ds = \sum \frac{\overline{\Delta s}_i}{\Delta z_i} \int_i^{i+1} T(z) \rho^*(z) dz \quad (16)$$

$$m^* = \int \rho^* ds = \sum \frac{\overline{\Delta s}_i}{\Delta z_i} \int_i^{i+1} \rho^* dz \quad (17)$$

The pressure and total air density are both assumed to follow an exponential profile with scale heights H_p and H_{ρ}^* respectively. The integral in Eq. (15) can be written as

$$\int_i^{i+1} P \rho^* dz = \frac{H_p H_{\rho}^*}{H_p + H_{\rho}^*} (P(z_i) \rho^*(z_i) - P(z_{i+1}) \rho^*(z_{i+1})) \quad (18)$$

From the ideal gas law

$$P = G \rho^* T \quad (19)$$

where G is the gas constant for air. Using this equation, the integral in Eq. (16) becomes

$$\int_i^{i+1} T \rho^* dz = \frac{1}{G} \int_i^{i+1} P dz = \frac{H_p}{G} (P(z_i) - P(z_{i+1})) \quad (20)$$

The density integral in Eq. (17) is the same as in Eq. (10):

$$\int_i^{i+1} \rho^* dz = H_{\rho}^* (\rho^*(z_i) - \rho^*(z_{i+1})) \quad (21)$$

The next section will describe the method used to calculate the refracted path Δs_j through each sublayer.

2.2 Atmospheric Refraction

The refraction of a light ray is due to the gradient of the index of refraction n , with the ray refracted in the direction of increasing n . To a close approximation, the refractivity $N = n - 1$ is proportional to the air density. See Appendix B for a discussion of the index of refraction of air. In a spherically symmetric atmosphere, $\text{grad } n$ is directed radially, and except in unusual circumstances, downward. The trajectory of the ray is determined by Snell's law for a spherically symmetric medium:²

$$n(r) r \sin \theta = c, \quad (22)$$

where θ is the angle of incidence at r and c is a constant that depends upon the particular path. If the ray is horizontal at r_T then $z_T = r_T - r_e$ is the tangent height and $c = n(r_T)r_T$. The curvature K of the refracted ray can be shown to be³

$$K = -\sin \theta \frac{n'}{n}, \quad (23)$$

where $n' = dn/dr$.

It is useful to define the quantity $R(r)$ as

$$R(r) = -\frac{r}{n/n'}. \quad (24)$$

R is simply the ratio of r to the radius of curvature of a ray tangent at r . R is a property of the atmospheric profile (not the particular path) and is a good measure of the importance of refraction at a given altitude. For example, for the U.S. Standard Atmosphere 1962, R is 0.16 at the ground and decreases approximately exponentially with a scale height of about 10 km. As an extreme example, if $R = 1.0$, a ray tangent at r will continue indefinitely to follow a circular path of radius r .

Consider now a point moving along the path within the layer defined by r_1 and r_2 as shown in Figure 1. At a point defined by the radius r and with an incidence angle θ as shown in Figure 2, the differential path length ds is

$$ds = -\frac{1}{\cos \theta} dr. \quad (25)$$

2. Born, M., and Wolf, E. (1964) Principals of Optics, Pergamon Press, Inc., N.Y., pp 121-123.

3. Meyer-Arendt, J.R., and Emmanuel, C.B. (1965) Optical Scintillation: A Survey of the Literature, National Bureau of Standards, Tech Note 225.

Eq. (22) can be used to eliminate θ in Eq. (25) giving:

$$ds = \left(1 - \frac{c^2}{n^2 r^2}\right)^{-1/2} dr \quad (26)$$

Eq. (26) can be integrated numerically to obtain s for a layer or sublayer.

The drawback with using Eq. (26) is that in the region near a tangent height (that is, $\sin \theta = c/nr$ approaches 1), the right-hand side of Eq. (26) goes to infinity and a different numerical algorithm must be used. An alternative formulation of this equation that avoids this problem is as follows. Define a new independent variable x as

$$x = -r \cos \theta \quad (27)$$

$$dx = -\left(\cos \theta - r \sin \theta \frac{d\theta}{dr}\right) dr \quad (28)$$

Differentiating Eq. (22) and using Eq. (24) gives

$$\frac{d\theta}{dr} = -\frac{\tan \theta}{r} (1 - R) \quad (29)$$

Substituting Eq. (29) into Eq. (28) gives

$$dx = -(1 - R \sin^2 \theta) \frac{dr}{\cos \theta} \quad (30)$$

Comparing Eq. (30) with Eq. (25) gives

$$ds = (1 - R \sin^2 \theta)^{-1} dx \quad (31)$$

In this form of the equation for ds , the right-hand side is a well-behaved function of r for all paths, including vertical and horizontal paths (except in the unusual circumstances that $R \geq 1$). The intermediate variable x is related to r by

$$x = -r \cos \theta = r \left(1 - \frac{c^2}{n^2 r^2}\right)^{1/2} \quad (32)$$

which is also a well-behaved function of r for all paths. In practice, the numerical integration of Eq. (31) is driven in terms of steps in r , from r to $r + \Delta r$. The

corresponding increment in x is calculated using Eq. (32). The integration of s from Eq. (31) is then straightforward.

It is also useful to calculate the values of the earth centered angle β and the bending ψ for the layer. From Figure 2, again,

$$\frac{d\beta}{dr} = \frac{\tan \theta}{r} \quad (33)$$

In terms of x :

$$\begin{aligned} \frac{d\beta}{dx} &= \frac{d\beta}{dr} \frac{dr}{dx} \\ \frac{d\beta}{dx} &= (1 - R \sin^2 \theta)^{-1} \frac{\sin \theta}{r} \end{aligned} \quad (34)$$

ψ is related to the other path quantities by

$$\psi = \pi + \beta - \alpha - \theta \quad (35)$$

so that

$$\frac{d\psi}{dx} = \frac{d\beta}{dx} - \frac{d\theta}{dx} \quad (36)$$

giving

$$\frac{d\psi}{dx} = (1 - R \sin^2 \theta)^{-1} \frac{R}{r} \sin \theta \quad (37)$$

In practice ψ is integrated along the path along with s and β is calculated from Eq. (35).

It is useful to examine Eq. (31) in some detail. It can be shown geometrically that dx equals ds in the case of a straight line, that is, no refraction. Correspondingly, the right-hand side of Eq. (31) approaches 1 as refraction becomes less important, that is, as either R or $\sin \theta$ goes to zero. At the other extreme, in the case of very strong refraction of a horizontal ray where the curvature due to refraction equals the curvature of the earth, R and $\sin \theta$ both equal 1 and the right-hand side of Eq. (31) becomes infinite. The path in this case is a circle for which $x = r \cos \theta$ is constant. For even stronger refraction where $R > 1$, the light ray is bent back toward the earth and the right-hand side of Eq. (31) becomes negative.

In this case, dx is also negative along the path. Finally, in the presence of a density inversion ($n' > 0$), R is negative and the ray is bent upwards.

2.3 Numerical Algorithm

This section will describe the numerical algorithm used to calculate the slant path and the absorber amounts through a single layer.

The integration of the slant path parameters s , β , and ψ and the absorber amounts is performed by dividing the layer into sublayers bounded by the altitudes z_j , $j = 1$ to J . The spacing of the sublayers is chosen so that the path increments are approximately equal to a nominal path increment $\Delta \tilde{s}$, where $\Delta \tilde{s}$ is determined by the required accuracy of the results. The integration always proceeds from the bottom of the layer to the top: the incidence angle θ at the bottom of the layer is assumed known as is the value of c [Eq. (22)].

The values of N , P , ρ , and ρ^* are interpolated exponentially from the values at the layer boundaries with scale heights H_N , H_P , H_ρ , and H_{ρ^*} respectively.

R is given by

$$R = \frac{r}{n/n'} = \frac{r N_1 e^{-z/H_N}}{H_N (1 + N_1 e^{-z/H_N})}, \quad (38)$$

where N_1 is the value of N at $z = 0$.

The numerical integration scheme proceeds as follows:

1. $\Delta r_j = \Delta \tilde{s} \cos \theta_{j-1}$
2. $r_j = r_{j-1} + \Delta r_j$
3. $\sin \theta_j = c / (n(r_j) r_j)$
4. $\cos \theta_j = -(1 - \sin^2 \theta_j)^{1/2}$
5. $x_j = -r_j \cos \theta_j$
6. $\Delta x_j = x_j - x_{j-1}$
7. $\left. \frac{ds}{dx} \right|_j = (1 - R_j \sin^2 \theta_j)$

8. $s_j = s_{j-1} + \frac{1}{2} \left(\left. \frac{ds}{dx} \right|_{j-1} + \left. \frac{ds}{dx} \right|_j \right) \Delta x_j$
9. $\left. \frac{d\psi}{dx} \right|_j = \left. \frac{ds}{dx} \right|_j \frac{R_j}{r_j} \sin \theta_j$
10. $\psi_j = \psi_{j-1} + \frac{1}{2} \left(\left. \frac{d\psi}{dx} \right|_{j-1} + \left. \frac{d\psi}{dx} \right|_j \right) \Delta x_j$
11. $m_j = m_{j-1} + \frac{\Delta s_j}{\Delta r_j} H_\rho (\rho(r_j) - \rho(r_{j-1}))$
12. $j = j + 1$
13. Go to 1.

Near a tangent height where $\cos \theta$ approaches zero, this scheme must be modified. First, Step 1 breaks down for $\cos \theta_1 = 0$ and Δs is replaced by

$$\Delta r_1 = \frac{\Delta s^2}{2r_1} \quad (39)$$

Secondly, the truncation error for $\cos \theta_j$ in Step 4 is excessive for computers with seven decimal digits of precision when $\sin \theta_j$ is greater than about 0.99999. To avoid this problem, $\cos \theta_j$ is calculated for $\sin \theta_j > 0.99999$ from:

$$\cos \theta(r) = -(2 y(r) - y^2(r))^{1/2} \quad (40)$$

and

$$y(r) = \int_{r_T}^r (1 - R(r)) \frac{\sin \theta}{r} dr \quad (41)$$

where r_T is the radius at the tangent height. [Eq. (40) and Eq. (41) are obtained by integrating Eq. (29).]

Note that the steps are driven in increments of r although the nominal independent variable is x . There are two reasons for this procedure. First, it is necessary to stop the integration at the upper boundary; this is done most conveniently when r drives the integration. Secondly, x is an analytic function of r

so that x_j can be calculated simply from r_j . The opposite is not true; an iterative scheme would be required to calculate r_j given x_j .

2.4 Examples of Air Mass Calculations

This section will present some examples of air mass calculations for total air, water vapor, and ozone for various geometries and atmospheric profiles using the program FSCATM. The cases were chosen to broadly represent the range of conditions likely to meet in spectroscopic observations of the atmosphere. In general, the results are presented both with and without the effects of refraction so that the reader may judge for himself under which circumstances refraction can be neglected.

The three atmosphere profiles used here are taken from McClatchey et al.^{4*} and were chosen to represent mean and extremes of temperature and of water-vapor and ozone concentrations found in the atmosphere. The profiles of temperature, total air density, water-vapor density, and ozone density up to 70 km are shown in Figure 3. The surface pressure for all three profiles is the same, 1013 mb.

The paths are described in terms of the following parameters: H1 is the observer's altitude, ANGLE is the zenith angle at the observer, and H2 is the altitude of the other end of the path. For a path out to space, H2 is the top of the atmospheric profile (here 100 km). Three geometries are presented here: (1) H1 = 0, H2 = 100 km, ANGLE varies from 0 to 90°, (2) H2 = 100 km, ANGLE = 90°, H1 varies from 0 to 50 km, and (3) H1 = 30 km, H2 = 100 km, ANGLE varies from 85° to about 95.5° at which point the path intersects the earth. Path 1 is relevant for ground-based observations, while paths 2 and 3 correspond to observations from balloon or aircraft. Path 2 is also relevant to satellite observations scanning the limb, where H1 is the tangent height and the integrated absorber amounts must, of course, be doubled.

These calculations were all performed with the index of refraction calculated at 2000 cm⁻¹ (5 μm). The effect on air mass of variations of the index of refraction with wavenumber are negligible between 500 and 20,000 cm⁻¹ (20 to 0.5 μm).

Although the term air mass refers properly only to the amount of air along a path, it will be applied here loosely to water vapor and ozone to refer to the integrated amount relative to a vertical path from ground to space for the same

* See Appendix A regarding the water vapor profiles.

4. McClatchey, R.A., Fenn, R.W., Selby, J.E.A., Volz, F.E., and Garing, J.S. (1972) Optical Properties of the Atmosphere (Third Edition), AFCRL-TR-72-0497, AD 679996.

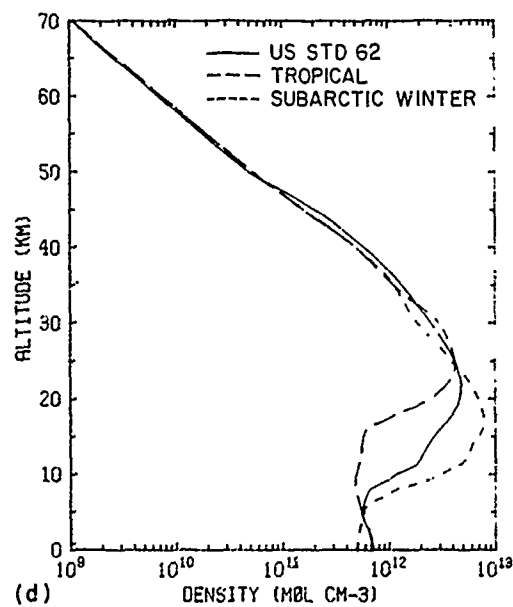
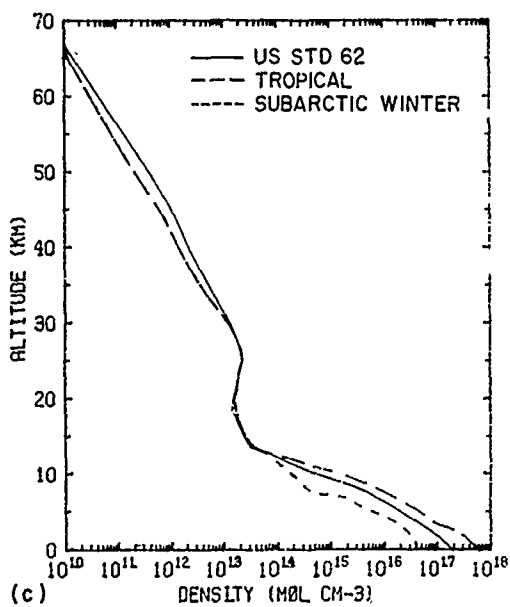
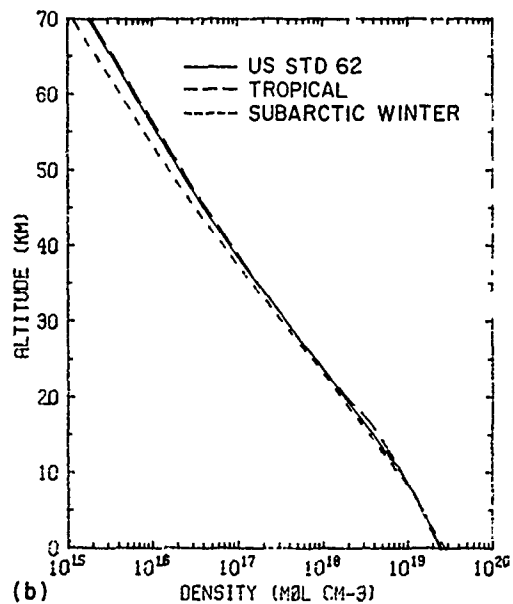
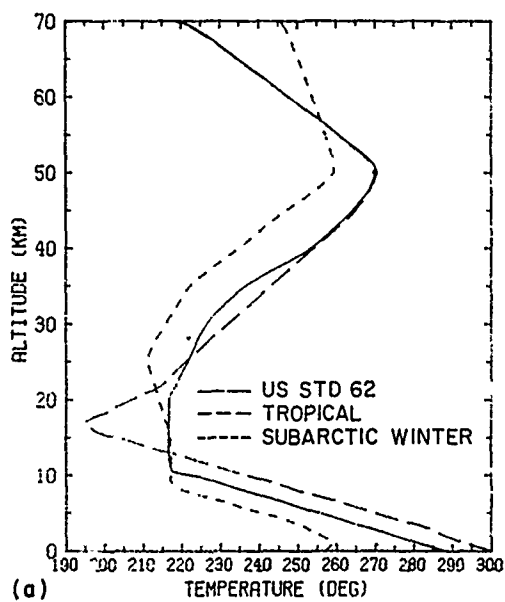


Figure 3. Profiles of Three Atmospheric Models of (a) Temperature, (b) Total Air Density, (c) Water Vapor, and (d) Ozone

vertical distribution. For the U.S. Standard Atmosphere 1962, one air mass refers to the following integrated absorber amounts:

air	2.15×10^{25} molecules cm^{-2}
water vapor	4.74×10^{22} molecules cm^{-2}
ozone	9.24×10^{18} molecules cm^{-2}

In the following graphs, U and \tilde{U} will represent the air mass for a refracted path and an unrefracted path respectively.

Figures 4 and 5 show the effect of the earth's curvature on air mass for a ground-based observer by comparing the air mass computed without refraction with the secant of the zenith angle. Figure 5 shows that the secant approximation is good to within 1 percent up to a zenith angle of 72° for a uniformly mixed gas, up to 80° for water vapor, but only up to 60° for ozone.

Figure 6 shows the same calculations as Figure 4 except that refraction is included. At 90° the air mass values for the three components are:

	<u>With Refraction</u>	<u>No Refraction</u>
air	38.1	35.1
H_2O	72.2	66.1
O_3	14.4	13.8

These values depend upon the atmospheric profile used; in this case it is the U.S. Standard Atmosphere 1962. Water vapor has the highest value since it is concentrated near the ground where the effective secant [ds/dz in Eq. (6)] is the highest. Conversely, ozone has the smallest air mass value since the ozone density profile peaks near 20 km, where the effective secant is relatively small.

Comparing Figure 7 with Figure 5 shows that the effect of refraction is smaller than that of the earth's curvature. At 90° , refraction increases the air mass by less than 10 percent, and the air mass can be computed neglecting refraction to better than 1 percent up to 86° for water vapor, 84° for a uniformly mixed gas, and 82° for ozone.

The air mass vs altitude for an observer looking out horizontally is shown in Figure 8. These curves mimic the density profiles of the components themselves, since for this path the bulk of the absorber is located within a few kilometers (vertically) of the observer's altitude. From Figure 9, the effect of refraction an air mass becomes less than 1 percent at 20 km for all three components.

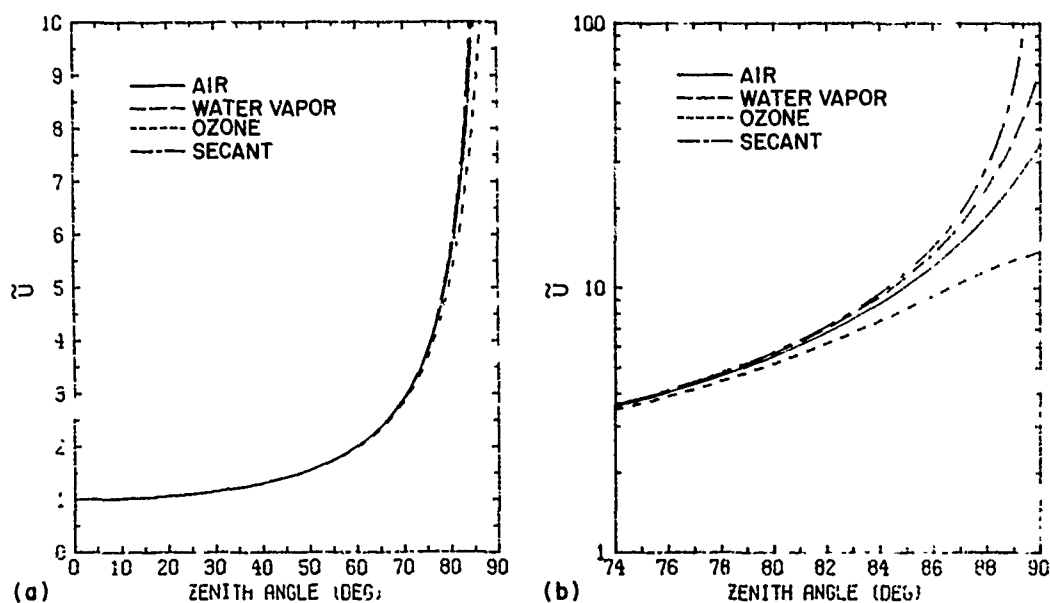


Figure 4. Air Mass (\tilde{U}) vs Zenith Angle for the Case: $H_1 = 0$, $H_2 = 100$ km U.S. Standard Atmosphere 1962, No Refraction. For reference, the secant of the angle is also shown: (a) 0 to 90° and (b) 74 to 90°

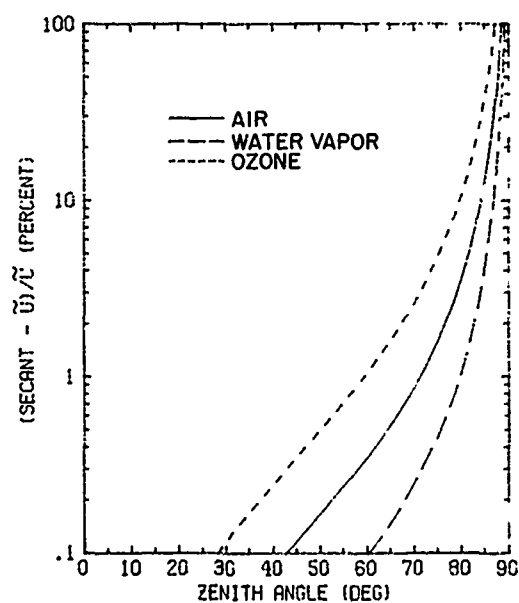


Figure 5. Relative Air Mass Error Due to the Secant Approximation vs Zenith Angle for the Case Shown in Figure 4

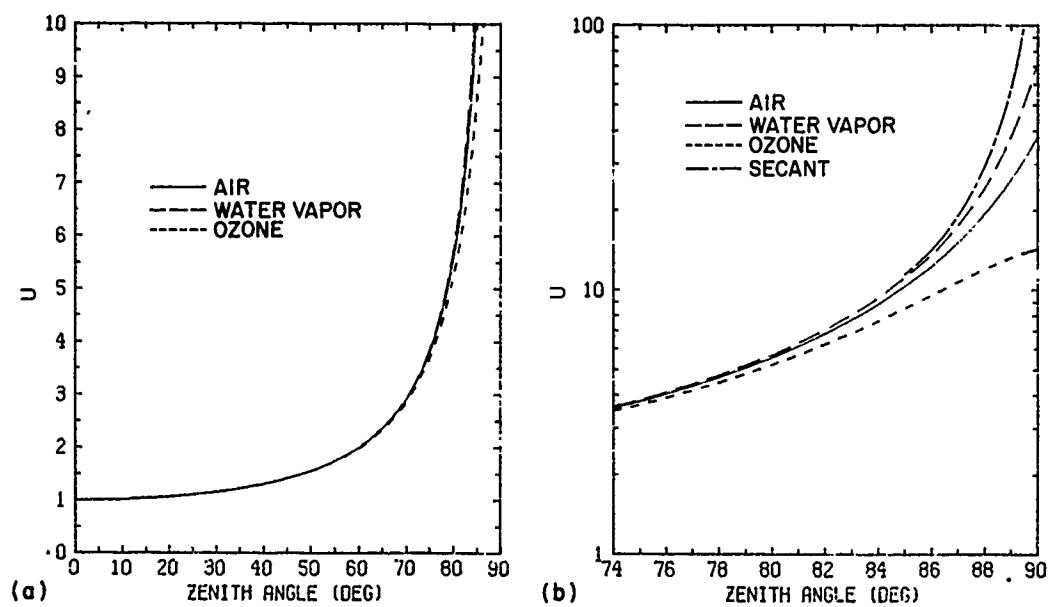


Figure 6. Air Mass (U) vs Zenith Angle for the Case $H_1 = 0$, $H_2 = 100$ km, U.S. Standard Atmosphere 1962, Including Refraction: (a) 0 to 90° and (b) 74 to 90°

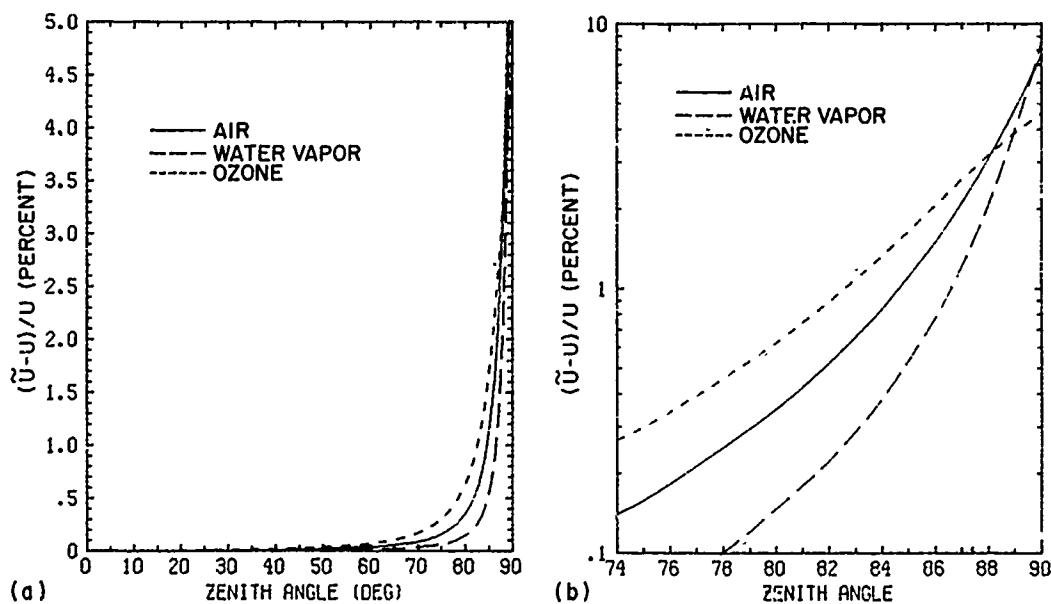


Figure 7. Relative Air Mass Error Due to Neglecting Refraction vs Zenith Angle for the Case in Figure 6: (a) 0 to 90° and (b) 74 to 90°

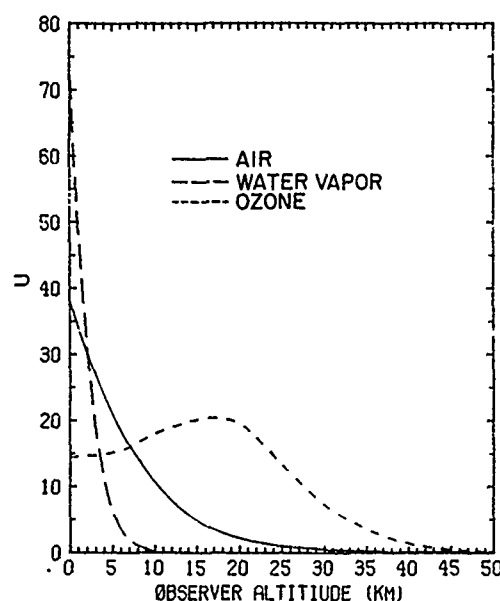


Figure 8. Air Mass (U) vs Observer Altitude (H_1) for the Case $H_2 = 100$ km, ZENITH ANGLE = 90° , U.S. Standard Atmosphere 1962, Including Refraction

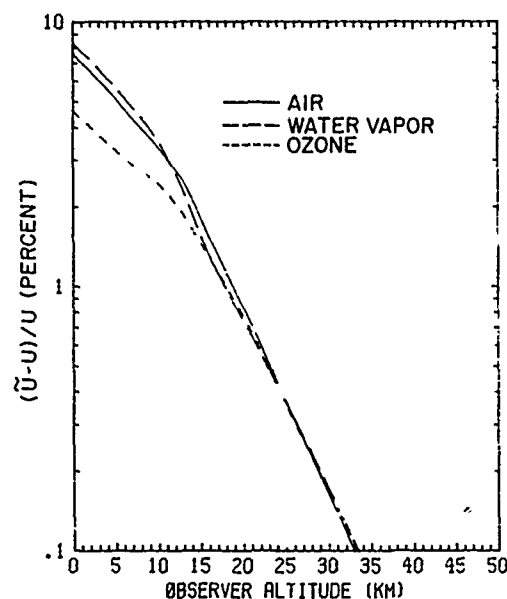


Figure 9. Relative Air Mass Error Due to Neglecting Refraction vs Observer Altitude for the Case in Figure 8

The variation of air mass with zenith angle for a typical stratospheric balloon-borne spectroscopic experiment is shown in Figure 10, with the error due to neglecting refraction in Figure 11. The zenith angle shown is the apparent zenith angle of the refracted ray such as would be measured at the observer. The tangent height vs zenith angle is shown on the right-hand axis of Figure 10. Also shown on Figure 10 is the sun's angular diameter for comparison (after Sneider⁵). If the sun is used as a source for a measurement, the air mass to different points in the sun can vary by more than a factor of 2 for large zenith angles. This effect is due to curvature: by comparison of the effect of refraction shown in Figure 11 is much less. The variation in air mass due to this effect can be the major source of uncertainty in a measurement and must be considered carefully.

Sneider's⁵ Figures 4 and 5 show comparisons similar to Figures 10 and 11 here; however, they are not directly comparable since his refracted and unrefracted paths do not have the same zenith angle at the observer. His calculations involve an observer looking at the sun: the unrefracted path follows a straight line to the sun with the zenith angle at the observer equal to the astronomical

5. Sneider, D. (1975) Refractive effects in remote sounding of the atmosphere with infrared transmission spectroscopy, *J. Atmos. Sci.* 32:2178-2184.

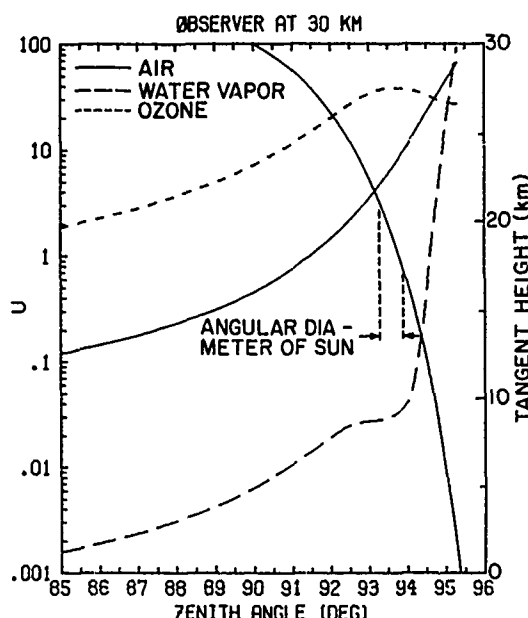


Figure 10. Air Mass (U) vs Zenith Angle for the Case $H_1 = 30$ km, $H_2 = 100$ km, U.S. Standard Atmosphere 1962, Including Refraction. Also shown are the tangent height vs zenith angle and the angular diameter of the sun

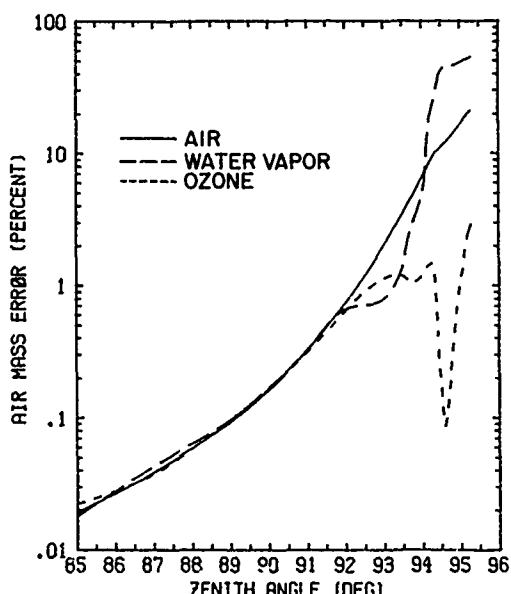


Figure 11. Relative Air Mass Error Due to Neglecting Refraction vs Zenith Angle for the Case in Figure 10

zenith angle. For the refracted path, the zenith angle at the observer is the apparent zenith angle, which is less than the astronomical zenith angle. It turns out that the effect of refraction appears greater for the geometry presented in Sneider's report than in this one.

Figures 12 and 13 demonstrate the effect of different atmospheric profiles on the absorber amount for two different paths. In Figure 12(a) the integrated amount for a uniformly mixed gas for a path from ground to space at 90° varies only 10 percent from a tropical to a Subarctic Winter atmosphere (assuming the same surface pressure). The water vapor amount, however, differs by a factor of 10 and the ozone amount by a factor of 2, due to different density profiles. For the path in Figure 13 (tangent height to space) the pressure at a given altitude is different for the three profiles so that the amounts for a uniformly mixed gas become equal at 3 km. The water amounts above 13 km become equal because the water vapor profiles above that altitude are about the same [see Figure 3(c)].

Different atmospheric profiles also produce different amounts of refraction. The difference in the tangent height between a refracted and an unrefracted ray coming in from space is shown as a function of the refracted tangent height in

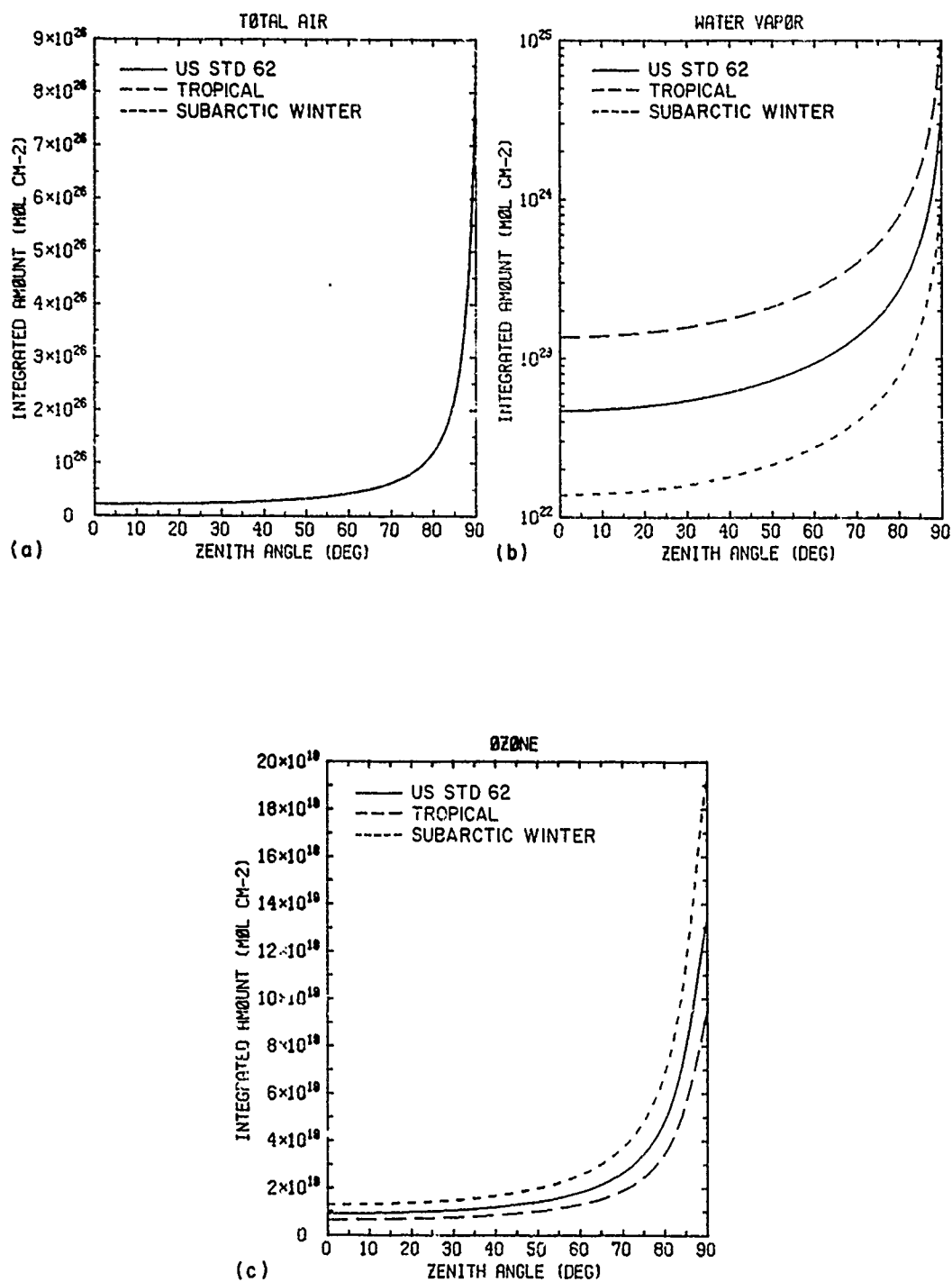


Figure 12. Integrated Absorber Amounts vs Zenith Angle for Three Atmospheric Profiles for the Case of $H_1 = 0$, $H_2 = 100$ km, Including Refraction: (a) Total Air (the Three Curves are Indistinguishable), (b) Water Vapor, and (c) Ozone

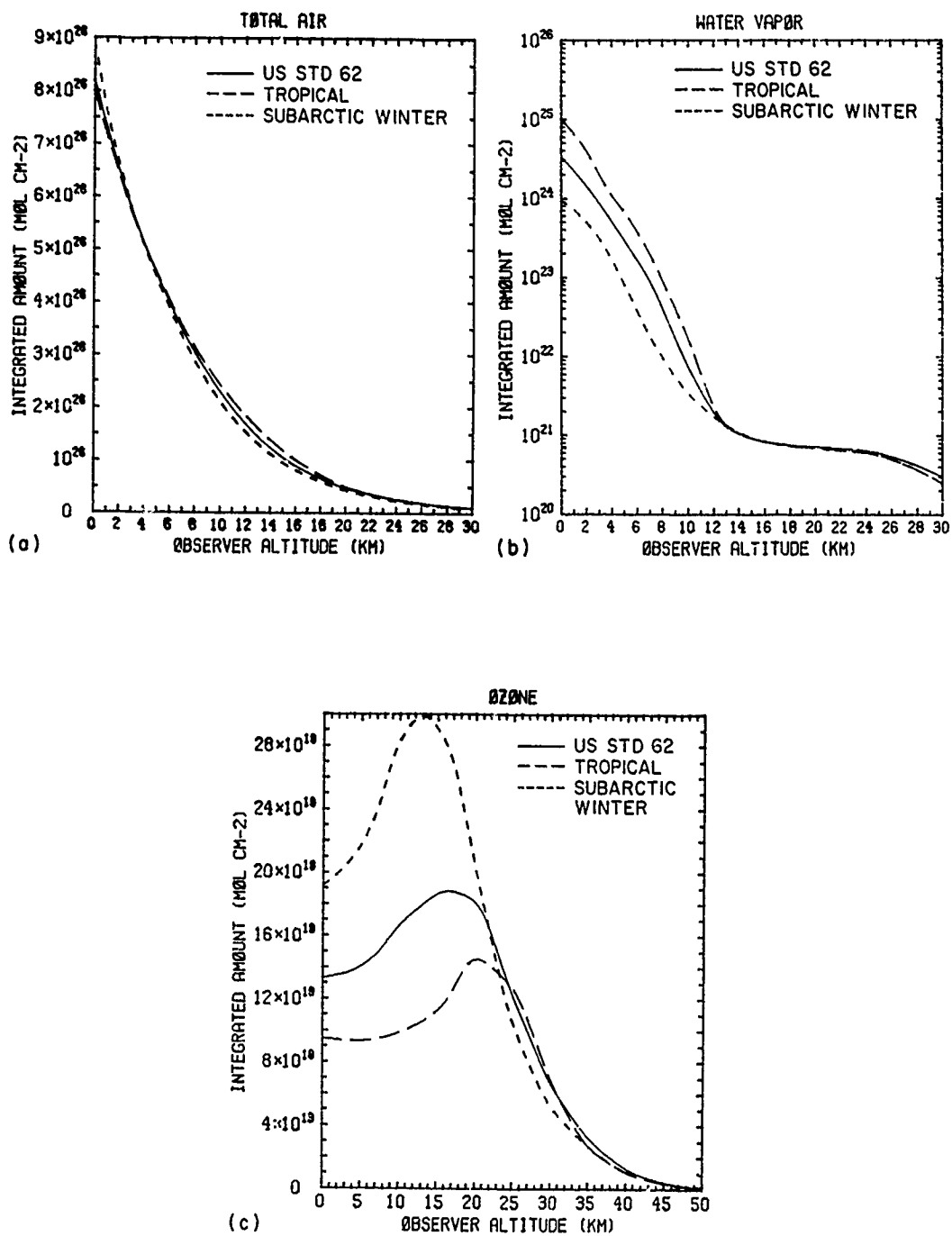


Figure 13. Integrated Absorber Amounts vs Observer Altitude for Three Atmospheric Profiles for the Case of ZENITH ANGLE = 90, $H_2 = 100$ km, Including Refraction: (a) Total Air, (b) Water Vapor, and (c) Ozone

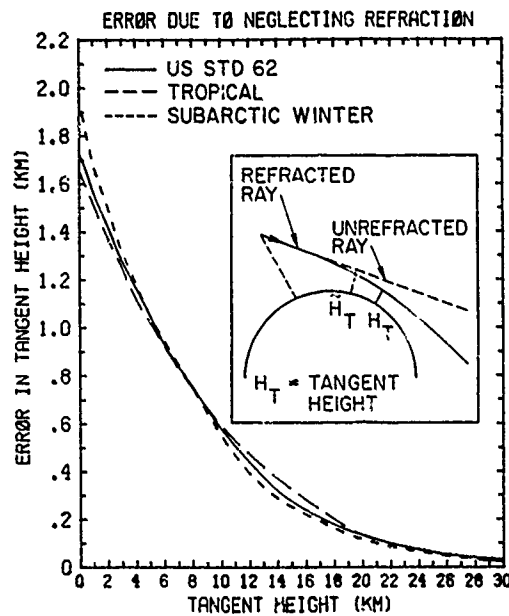


Figure 14. Unrefracted Tangent Height Minus Refracted Tangent Height vs Refracted Tangent Height for Three Atmospheric Profiles. The diagram illustrates the geometry involved

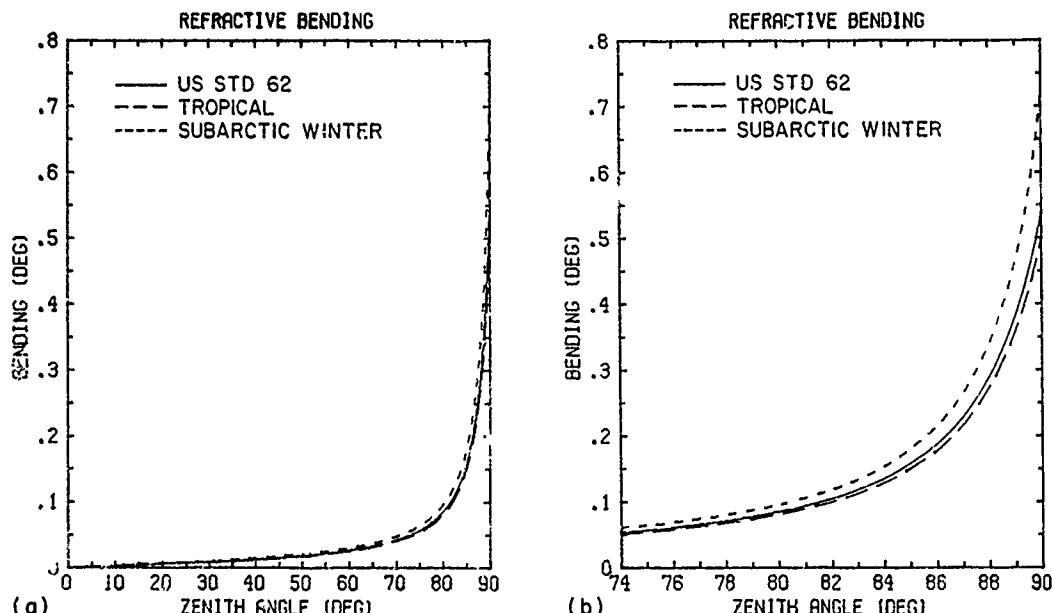


Figure 15. Refractive Bending vs Zenith Angle for Three Atmospheric Profiles for the Case $H_1 = 0$, $H_2 = 100$ km: (a) 0 to 90° and (b) 74° to 90°

Figure 14 for the three atmospheric profiles (the geometry is shown schematically in the inset). The total refractive bending is shown in Figure 15 vs zenith angle for a path from ground to space and in Figure 16 vs observer altitude for a path tangent at that altitude. Note that the total bending for a path from the ground at 90° for the U.S. Standard Atmosphere 1962 and for the tropical atmosphere is about 0.5° , which is the same as the solar diameter of 0.5° .

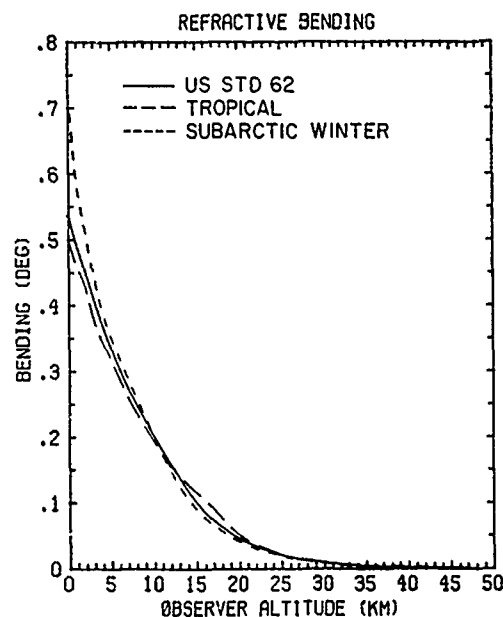


Figure 16. Refractive Bending vs Observer Altitude for Three Atmospheric Profiles for the Case $H_2 = \text{space}$, $\text{ZENITH ANGLE} = 90^\circ$

3. FSCATM: A PROGRAM TO CALCULATE AIR MASS

FSCATM calculates the integrated absorber amounts and density-weighted pressure and temperature for an arbitrary slant path through the atmosphere. FSCATM is specifically designed to calculate and format the atmospheric inputs for the atmospheric transmittance/radiance program FASCODE.² The form of the input parameters mimics as closely as possible the input parameters to the well known low resolution atmospheric transmittance/radiance program

LOWTRAN.⁶ In fact, the core subroutines from FSCATM will replace the geometry subroutines in the next version of LOWTRAN. The six representative atmospheric profiles included in FSCATM are the same as in LOWTRAN although the densities are in different units.

3.1 Program Usage

Four standard control cards control the operation of FSCATM while other cards may be required to define non-standard conditions. The program input consists of a set of control cards read in on UNIT = 5 defining the atmospheric profile, the path, and the output layer boundaries. Output consists of a report written to UNIT = 6 providing a complete description of the profile, path, and absorber amounts and describing any error conditions encountered. Optionally, the mean pressure and temperature and the integrated absorber amounts for each layer are written to UNIT = 7. Examples of program input and output will be shown later in this section.

3.1.1 INPUT

The four standard atmospheric input control cards are shown in Table 1 and are discussed below.

3.1.1.1 Card 1 Model Parameters: MODEL, ITYPE, IBND, NOZERO, NOPRNT, KMAX, IPUNCH, RE

The parameter MODEL selects one of the six standard atmospheric profiles (1 to 6)^{*} or allows the user to read in either a profile (MODEL = 7) or a set of horizontal path parameters (MODEL = 0). (See the section on non-standard conditions for the use of MODEL = 0 or 7.) ITYPE selects one of three types of path: (1) a horizontal path at constant temperature and pressure, (2) a slant path from H1 to H2, (3) a slant path from H1 to space (equal to the highest level in the atmospheric profile, 100 km for MODEL = 1 to 6). IBND controls the layering of the final output: If IBND = 0, the program automatically selects a set of output layers based on user-supplied parameters from Card 4. If IBND is greater than 0, the user directly inputs the output layer boundaries on Card 4.

Normally, the program will zero out the absorber amounts of a gas for a layer if the amount for that layer and those above it are less than 0.1 percent of the total amount. NOZERO = 1 suppresses this option. This option is used to

^{*}See Appendix A for a discussion of these atmospheric profiles.

6. Kneizys, F.X., Shettle, E.P., Gallery, W.O., Chetwynd, J.H., Jr., Abreu, L.W., Selby, J.E.A., Fenn, R.W., and McClatchey, R.A. (1980) Atmospheric Transmittance/Radiance: Computer Code LOWTRAN 5, AFGL-TR-80-0067, AD A088215.

Table 1. FSCATM Control Cards

Control Card 1: MODEL, ITYPE, IBND, NOZERO, NOPRNT, KMAX,
IPUNCH, RE
(7I5, 5X, F10.4)

MODEL = 0: user-supplied horizontal path parameters
1: tropical atmospheric model
2: midlatitude summer
3: midlatitude winter
4: subarctic summer
5: subarctic winter
6: U.S. Standard Atmosphere 1962
7: user-supplied atmospheric profile

ITYPE = 1: horizontal path (constant pressure)
2: slant path from H1 to H2
3: slant path from H1 to space

IBND number of boundary altitudes for the FAS0CD1 layers:
IF IBND .GT. 0, user-supplied boundaries
IF IBND .EQ. 0, auto layering is selected

NOZERO = 1: suppresses zeroing of small amounts
Default = 0

NOPRNT = 1: selects short printout. Default = 0

KMAX number of molecular species. Default = 7, max = 20.
IF KMAX .LT. 0, a ray trace is done but no amounts are
calculated.

IPUNCH = 1: write layer amounts to unit IPU=7. Default = 0.

RE radius of the earth, defaults:

MODEL = 1, RE = 6378.39 km
2, 3, 6, 7, RE = 6371.23 km
4, 5, RE = 6356.91 km

The formats for the remaining control cards are different depending on
whether the path is horizontal (ITYPE=1) or slant (ITYPE=2 or 3).

For a slant path (ITYPE=2 or 3):

Control Card 2: H1, H2, ANGLE, RANGE, BETA, LEN
(5F10.4, I5)

H1 altitude of the observer or receiver (km)

H2 altitude of the other endpoint of the path (ITYPE=2) or
the tangent height (ITYPE=3)

ANGLE zenith angle at H1 (degrees)

RANGE length of the path from H1 to H2 (km):

BETA earth centered angle for the path H1 to H2 (deg)

LEN =0, short path; =1, long path through a tangent height.
LEN is used only when ANGLE is greater than 90.0 and
H1 is greater than H2. Default = 0.

Control Card 3: V1, V2
(2F10.3)

V1, V2 initial and final wavenumbers for use in calculating the
Doppler halfwidth used in creating the FASCODE layers
and in calculating the index of refraction (cm^{-1})

Table 1. FSCATM Control Cards (Contd)

Control Card 4:

IF IBND .EQ. 0 (autolayering selected)

AVTRAT, TDIFF1, TDIFF2 (3F10.3)

AVTRAT = max Voigt width ratio across a layer. Default = 2.0

TDIFF1 = max temp difference (K) across a layer at HMIN
(=lowest altitude along the path). Default = 15.0 K

TDIFF2 = max temp difference (K) across a layer at HMAX
(=highest altitude along the path). Default = 30.0 K

IF IBND .NE. 0 (user-supplied FASCOD1 layer boundaries)

(ZBND(IB), IB=1, IBND) (8F10.3)

ZBND altitudes of FASCOD1 layer boundaries

If MODEL=7, the input atmospheric profile is read in after Control Card 4 in the following format:

IMOD, HEADER(I5, /, 3A8)

IMOD = number of levels in the profile

HEADER = 24-character describing the profile

Z, P, T, TD, RH, PPH20, DENH10, AMSMIX (8F10.3)

(VMIX(K), K=1, KMAX) (8E10.3)

two (or more) card images for each of the IMOD levels. See the text for the definition and usages of TP, RH, PPH20, DENH20, AMSMIX, and VMIX.

For a horizontal path (ITYPE=1):

Control Card 2:

For MODEL = 1 to 7:

Z, RANGE (2F10.3)

For MODEL = 0:

RANGE, P, T, TD, RH, PPH20, DENH20, AMSMIX (8F10.3)

(VMIX(K), K=1, KMAX) (8E10.3)

where Z and RANGE are the altitude and range of the path, both in km. For MODEL = 1 to 7, the pressure, temperature, and densities are interpolated from the model atmosphere. For MODEL = 0, see the text for the definition and usages of TP, RH, PPH20, DENH20, AMSMIX, and VMIX. If the volume mixing ratio of O₃ is not supplied for MODEL = 0, it is computed using a value for the volume mixing ratio of 40. E-9.

Control Cards 3 and 4: not used

For MODEL = 7, the input atmospheric profile is read in after Control Card 2 as for a slant path.

save computation time in the line-by-line computation since the computation time is proportional to the number of spectral lines in the calculation. NOPRNT = 1 selects a short form of the output on UNIT = 6 by suppressing the printing of the tables of the atmospheric profile, the slant path, and the layer amounts. KMAX is the number of molecular species for which the amounts are calculated and defaults to 7. The order of the molecules corresponds to the order on the AFGL Atmospheric Line Parameters Compilation^{7*} and the Trace Gas Compilation⁸ and is listed in Table 2. To calculate amounts for molecules other than the first seven, the user must select the MODEL = 7 option and read in an atmospheric profile including the profiles of the desired molecules, up to at most 20. If KMAX is less than zero, a ray trace is performed but no amounts are calculated. RE is the radius of the earth in KM. It can be changed to account for variations in the radius with latitude or to model the atmosphere of other planets.

3.1.1.2 Card 2 Slant Path Parameters: H1, H2, ANGLE, RANGE, BETA, LEN

The format for Card 2 and following are different depending on whether ITYPE is 1 (horizontal path) or 2 or 3 (slant paths). The slant paths will be discussed first.

The slant path parameters are illustrated in Figure 17. Only two or three of the first five parameters on Card 2 need be specified to define the slant path. See Table 3 for the allowable combinations of slant path parameters. The distinction between H1 and H2 is important when calculating radiance, since the radiance for the path from H1 to H2 is not the same as that from H2 to H1. ANGLE is the apparent or measured zenith angle at H1 and is different from the astronomical or unrefracted zenith angle. Note from Table 3 that when RANGE is a supplied parameter, H2 or ANGLE is calculated assuming no refraction and the refracted path is followed using that value. The resulting path will have a value of RANGE different from the input value, and if the path goes through a tangent height, the difference can be substantial. The parameter LEN is demonstrated in Figure 18.

Certain combinations of slant path parameters represent impossible geometries, for example, H1 = 10 km, H2 = 5 km, ANGLE = 60 deg. These cases are flagged as errors and the program stops. If a slant path intersects the earth, for

*For current version see Rothman, L.S. (1981) AFGL atmospheric absorption line parameters compilation: 1980 version, Appl. Opt. 20:791.

7. McClatchey, R.A., Benedict, W.S., Clough, S.A., Burch, D.E., Calfee, R.F., Fox, K., Rothman, L.S., and Garing, J.S. (1973) AFGL Atmospheric Absorption Line Parameters Compilation, AFCRL-TR-73-0096, AD 762904.
8. Rothman, L.S., Goldman, A., Gillis, J.R., Tipping, R.H., Brown, L.R., Margolis, J.S., Maki, A.G., and Young, L.D.G. (1981) AFGL trace gas compilation: 1980 version, Appl. Opt. 20:1323-1328.

Table 2. Molecular Species

	Molecule	Mwt*	v^\dagger		Molecule	Mwt*	v^\dagger
1	H ₂ O	18.015	0	11	NH ₃	17.03	0
2	CO ₂	44.010	322	12	HNO ₃	63.01	0
3	O ₃	47.998	0	13	OH	17.00	0
4	N ₂ O	44.01	0.27	14	HF	20.01	0
5	CO	28.011	0.19	15	HCl	36.46	0
6	CH ₄	16.043	1.5	16	HBr	80.92	0
7	O ₂	31.999	2.0948×10^5	17	HI	127.91	0
8	NO	30.01	0	18	ClO	51.45	0
9	SO ₂	64.06	0	19	OCS	60.08	0
10	NO ₂	46.01	0	20	H ₂ CO	30.03	0

*Molecular weight, from CRC, Handbook of Chemistry and Physics, 1971. The molecular weight is the average for the various isotopes weighted by their natural abundance.

† Default volume-mixing ratio in parts per million used for MODEL = 7 from U.S. Standard Atmosphere 1976.⁹

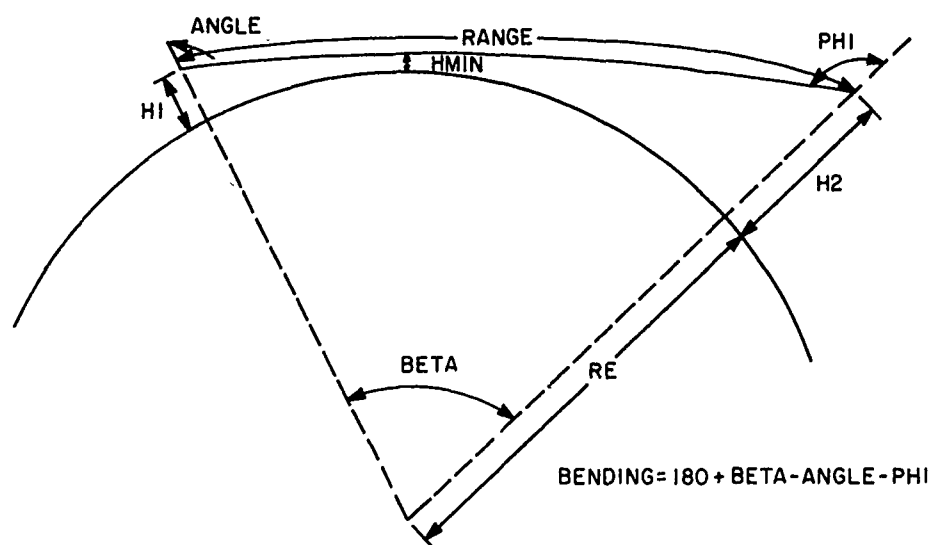


Figure 17. The Slant Path Parameters H1, H2, ANGLE, PHI, RANGE, BETA, and HMIN

9. (1976) U.S. Standard Atmosphere 1976, NOAA - S/T 76-1562, U.S. Government Printing Office.

Table 3. Allowable Combinations of Slant Path Parameters

Case	ITYPE	H1	H2	ANGLE	RANGE	BETA	LEN (Optional)
2A	2	*	*	*			(*)
2B	2	*		*	*		
2C	2	*	*		*		
2D	2	*	*			*	
3A	3	*		*			
3B	3	*	*				
			(HMIN)				

- 2A: LEN option is available only when $H1 > H2$ and $ANGLE > 90$. Otherwise, LEN is set in the program.
- 2B: H2 calculated assuming no refraction. Calculated RANGE will differ from the input value.
- 2C: ANGLE calculated assuming no refraction. Calculated RANGE will differ from the input value.
- 2D: Exact ANGLE is calculated by iteration of the path calculation.
- 3B: H2 is interpreted as HMIN = tangent height. H2 is reset to highest profile boundary.

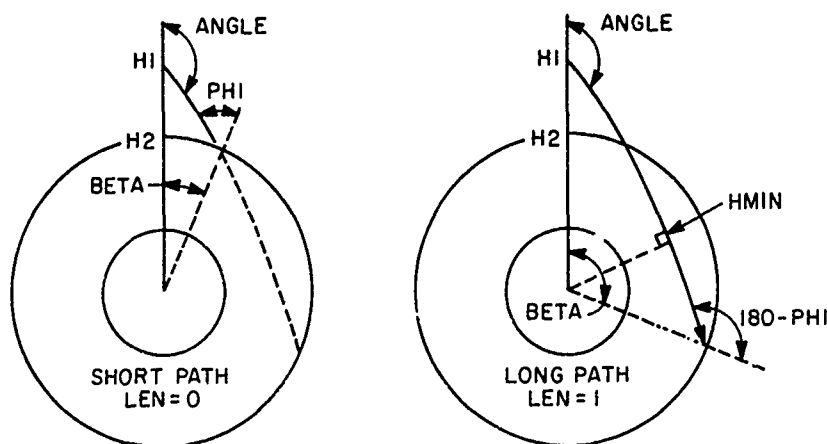


Figure 18. Demonstration of the Parameter LEN

example, $H1 = 10$ km, $H2 = 20$ km, $ANGLE = 100$ deg, the action of the program depends upon $ITYPE$. If $ITYPE = 2$, an error is flagged and the program stops. If $ITYPE = 3$, $H2$ is reset to 0, a message is printed, and the program continues.

It is possible to specify a value for $H1$ and/or $H2$ that is greater than the highest altitude in the atmospheric profile, for example, $H1$ might be a satellite altitude (for $MODEL = 1$ through 6, the highest boundary is at 100 km). In this case, the program resets $H1$ and/or $H2$ to the highest profile altitude $ZMAX$ and recomputes $ANGLE$ at $ZMAX$, assuming no refraction. This procedure is necessary because the density profiles above the top of the atmosphere are poorly defined and because the calculation time for the path above the atmosphere may be excessive (for example, for geosynchronous altitudes). Note also that for the Case 2D in Table 2 ($H1$, $H2$, $BETA$) $H1$ and $H2$ are not reset in the iterative calculation of $ANGLE$ so this case can be relatively time-consuming.

3.1.1.3 Card 3 Frequency Range: $V1$, $V2$

The average of $V1$ and $V2$ is used to calculate the Doppler halfwidth used in creating the output layers and to calculate the index of refraction. $V1$ and $V2$ need not correspond to the range of the spectral calculation, if for example the user wants to run cases in two different spectral regions with identical paths and output layers.

3.1.1.4 Card 4 Output Layering

If $IBND = 0$ on Card 1, the program generates its own set of output layer boundaries based on the values of $AVTRAT$, $TDIFF1$, and $TDIFF2$. $AVTRAT$ specifies the maximum allowable ratio of the Voigt halfwidth from one output boundary to the next highest for a molecule of molecular weight 36 and Lorentz halfwidth at 1013 mb and 296K of 0.1 cm^{-1} . $TDIFF1$ and $TDIFF2$ define the maximum allowable temperature difference across an output layer for a layer at $HMIN$ and $HMAX$ respectively. The actual temperature difference for a particular layer is determined by exponentially interpolating $TDIFF1$ and $TDIFF2$ to the altitude of bottom of the layer. The layers produced by this procedure will satisfy approximately both constraints. The defaults provided ($AVTRAT = 2.0$, $TDIFF1 = 15K$ and $TDIFF2 = 30K$) will produce a set of output layers generally suitable for general survey calculations. The user should, however, experiment with finer layering and critically examine the results in view of his accuracy requirements.

If $IBND$ is greater than zero, the user supplies its own output layer boundaries. These need not include the path endpoints and may extend above and below the endpoints. The program will edit this set of output boundaries to one that extends from the lowest to the highest altitude along the path and includes $H1$ or $H2$ if they

fall in the middle. The zeroing option on Card 1 may further reduce this set of layers under certain circumstances.

3.1.1.5 Horizontal Path: Z, RANGE, P, T, TD, PPH20, DENH20, AMSMIX, VMIX

For a horizontal path (ITYPE = 1, MODEL = 0 or MODEL = 1 to 7), Card 2 contains the only remaining parameters that need be specified and the format is different for the two cases. For an ITYPE = 1, MODEL = 1 through 7 case, only the altitude Z and path length RANGE need be specified. The program will interpolate the pressure, temperature, and densities to the given altitude. For a MODEL = 0 case, the user must supply the path length, pressure P, temperature T, water vapor amount, and volume mixing ratios for the other gases. See the next section on non-standard profiles for the definitions and usages of the various water vapor parameters and the conventions regarding the uniformly mixed gases. If no value for the ozone volume-mixing ratio is supplied, the surface value of 40×10^{-9} ppmv is assumed, taken from U.S. Standard Atmosphere 1976.⁹

3.1.1.6 Non-Standard Profiles

The MODEL = 7 option on Card 1 allows the user to read in an atmospheric profile, for example, from a radiosonde ascent. The profile is read in after Card 4 for ITYPE = 2 or 3 and after Card 2 for ITYPE = 1. The necessary parameters for each level are: the altitude, pressure, temperature, water vapor amount, and volume mixing ratios of the other gases. The water vapor amount can be specified in any one of six ways: VMIX = volume mixing ratio (ppm), AMSMIX = mass mixing ratio (gm kg^{-1}), DENH20 = mass density (gm m^{-3}), PPH20 = partial pressure (mb), RH = relative humidity (percent), or TD = dew point ($^{\circ}\text{C}$). If more than one of these values is given for the same level, the first non-zero value in the above list is used. A dew-point temperature of zero is a valid input and is assumed if all the water vapor parameters are left zero. To specify no water vapor, specify any negative value for the volume mixing ratio. (The dew point temperature should not be confused with the wet bulb temperature of a wet and dry bulb thermometer.)

If the volume mixing ratios for the uniformly mixed gases (K = 2 = CO_2 , 4 = N_2O , 5 = CO, 6 = CH_4 , 7 = O_2) are not supplied, then the following values are used:

Default Volume-mixing Ratios

CO_2	N_2O	CO	CH_4	O_2
322×10^{-6}	0.27×10^{-6}	0.19×10^{-6}	1.5×10^{-6}	0.20948

These default values, especially for CO, are different from those used to calculate the densities for models 1 through 6 taken from Optical Properties of the Atmosphere, Third Edition.⁴ If no profile for ozone is supplied, the ozone density is left at zero. To specify a zero density for a gas, read in any negative value for the volume mixing ratio.

3.1.2 OUTPUT

The program output consists of a descriptive report written to UNIT = 6 and optionally, the layer-by-layer results written to UNIT = 7. See the sample output following for examples of both outputs. The report on UNIT = 6 is largely self-explanatory. It should be noted, however, that the absorber amounts for a layer are for a single pass through the layer even if the path passes through the layer twice, as for a tangent path. The total amount listed does account for the two passes through a layer. Also, the parameter ZETA in the table of FASCODE output layer boundaries is defined as the ratio of the Lorentz to the Lorentz plus Doppler halfwidths (at half height).

The file written to UNIT = 7 consists of, first of all, a card with the number of layers to follow and 70 characters describing the atmospheric profile and the path. Next is the layer-by-layer data on two cards or more per layer. Card 1 contains the mean pressure, temperature, ICNTRL, and a 20-character layer description field. Card 2 contains the molecular absorber amounts in the order shown in Table 2 with the following exception. The amount in the eighth position is for N₂, which is used by FASCODE to calculate foreign broadened water-vapor continuum. The amounts for the remaining molecules start in position 9 beginning with molecule number 8 (NO). The ICNTRL parameter is used to describe the relationship between that layer and the rest of the path and is illustrated in Figure 19. For a tangent path, the layers that the path traverses twice (the symmetric layers) have ICNTRL = 2. The asymmetric layers (if any) on the near side of H1 have ICNTRL = 1, while the asymmetric layers (if any) on the far side

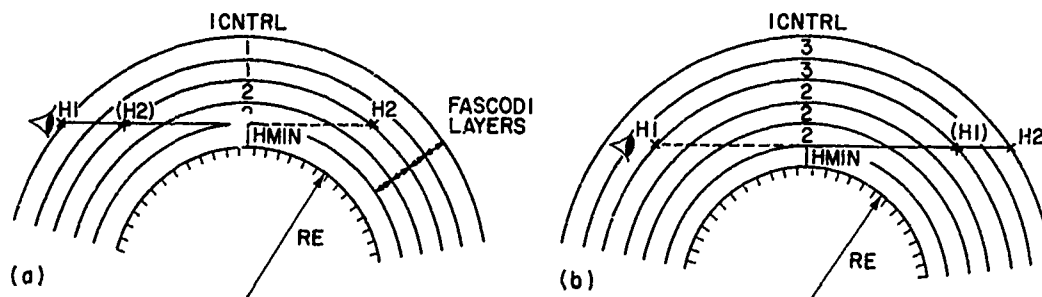


Figure 19. The Parameter ICNTRL for Two Tangent Paths

of H1 have ICNTRL = 3. For a path that is not a tangent path, then for a looking up case (H1 less the H2) ICNTRL = 3 and for a looking down case, ICNTRL = 1. For a horizontal path ICNTRL = 0.

3.2 Sample Input and Output

The input and output for four sample cases is listed in Table 4. Case 1, shown in Table 4a, models the conditions of a set of measurements taken at the South Pole.¹⁰ These measurements were taken by a ground based instrument at 2.9 km elevation looking at the sun, with a solar zenith angle of 67.7°. On Card 1, the Subarctic Winter Atmosphere (MODEL = 5) was selected because it contains the least amount of water vapor. ITYPE = 3 selects a slant path from H1 to the top of the atmosphere profile, here 100 km. The remaining parameters on Card 1 are left zero to select the defaults. In particular, IBND = 0 causes the program to generate its own output layers on the basis of the parameters on Card 4.

On Card 2, H1 is the altitude of the observer, here 2.9 km, and ANGLE is the measured zenith angle at H1. The other parameters are left blank and are calculated by the program. On Card 3, the initial and final wavenumbers are simply averaged and the average value is used to calculate the index of refraction and to produce the output layering. Card 4 is left blank to select the defaults that are 2.0, 15.0, and 30.0 for AVTRAT, TDIFF1 and TDIFF2 respectively.

The first page of the output for this case simply echoes the input cards and shows the supplied default values. A list of the atmospheric profiles follows. Next the path parameters are shown reduced to the standard form H1, H2, ANGLE, PHI, HMIN, and LEN: any allowed set of parameters (see Table 3) is reduced to this form. The output layer boundaries generated internally are shown next. These boundaries satisfy the requirements that: (1) the ratio of the average Voigt width across a layer is less than AVTRAT and, (2) the temperature difference across a layer is less than TDIFF. The value of TDIFF at any altitude is found by exponentially interpolating TDIFF1 and TDIFF2 to that altitude. A selected boundary is always rounded down to the nearest 0.1 km. In this case the temperature criterion determines the thickness of the first two layers while the Voigt ratio determines the next five. The Voigt ratio algorithm is only approximate so that the actual Voigt ratio may be slightly more than AVTRAT. The parameter ZETA is the ratio of the Lorentz to the Lorentz plus Doppler halfwidths.

10. Blatherwick, R.D., Murcray, F.J., Murcray, F.H., Goldman, A., and Murcray, D.G. (1982) Atlas of south pole IR solar spectra, Appl. Opt. 21:2658-2659.

Table 4a. Sample Input and Output - Case 1

```
*****INPUT CASE 1*****
5      3
      2.9      67.7
      880.0    890.0
      0.0      0.0      0.0
*****OUTPUT CASE 1*****
1      *****PROGRAM FSCATH*****      01/11/83      11.03.08.

CONTROL CARD 1: MODEL AND OPTIONS
MODEL      =      5
ITYPE      =      3
IBND       =      0
NOZERO     =      0
NOPRNT     =      0
KMAX       =      0
IPUNCH     =      0
RE         =      0.000 KM

CONTROL CARD 1 PARAMETERS WITH DEFAULTS:
MODEL      =      5
ITYPE      =      3
IBND       =      0
NOZERO     =      0
NOPRNT     =      0
KMAX       =      7
IPUNCH     =      0
RE         =      6356.910 KM

SLANT PATH SELECTED, ITYPE =      3

CONTROL CARD 2: SLANT PATH PARAMETERS
H1         =      2.9000 KM
H2         =      0.0000 KM
ANGLE      =      67.7000 DEG
RANGE      =      0.0000 KM
BETA       =      0.0000 DEG
LEN        =      0
```

Table 4a. Sample Input and Output - Case 1 (Contd.)

CASE 31: GIVEN H_1 $H_2 \approx$ SPACE ANGLE

ESIAN- BATH PARAMETERS IN STANDARD FORM

H1	=	2.900 KM
H2	=	100.000 KM
ANGLE	=	67.700 DEG
PHI	=	114.288 DEG
HMIN	=	2.900 KM
HEN	=	0

FASCODE LAYER BOUNDARIES PRODUCED BY THE AUTOMAYIC LAYERING ROUTINE AUTLAY
THE USER SHOULD EXAMINE THESE BOUNDARIES AND MODIFY THEM IF APPROPRIATE
THE FOLLOWING PARAMETERS ARE USED:

AVIRAT	2.00	=	MAX RATIO OF VOIGT WIDTHS
TDIFF1	15.00	=	MAX TEMP DIFF AT HMIN
TDIFF2	30.00	=	MAX TEMP DIFF AT HMAX
HALZERO	.100	=	AVERAGE LORENTZ WIDTH A* STP
WAVMNT	36.00	=	AVERAGE MOLECULAR WEIGHT
WAVEPR	85.00	=	AVERAGE WAVELENGTH

I	Z (KM)	P (MB)	T (K)	LOGRNTZ (CM-1)	DOPPLER (CM-1)	ZETA	VOIGT (CM-1)	VOIGT RATIO	BEND (DEG)	TSAR (K)	PBAR (MB)	BEND (DEG)	PHI (DEG)	RHOBAR (MOL CM-3)
1	2.300	698.990	253.020	.07355	.00024	.989	.07356	1.37	14.8					
2	5.400	486.982	238.160	.05358	.00092	.985	.05359	1.34	14.9					
3	7.600	351.608	223.280	.03995	.00079	.981	.03997	1.99	6.1					
4	12.100	173.856	217.200	.02033	.00078	.963	.02036	1.98	9					
5	16.500	87.175	216.300	.01006	.00078	.928	.01012	1.99	2.7					
6	21.000	42.770	213.600	.00497	.00077	.866	.00509	2.02	1.5					
7	25.900	19.558	212.064	.00228	.00077	.748	.00252	2.04	7.7					
8	33.000	6.408	218.720	.00073	.00078	.434	.00133	1.33	18.4					
9	41.400	1.843	238.144	.00020	.00082	.199	.00032	1.05	19.7					
10	49.400	.619	257.824	.00007	.00035	.072	.00036	1.08	20.8					
11	77.300	.012	237.013	.00000	.00031	.002	.00081	1.06	25.5					
12	98.700	.000	211.547	.00000	.00077	.000	.00077	1.00	1.5					
13	100.000	.000	210.000	.00000	.00077	.000	.00077	0.00	0.0					

CALCULATION OF THE REFRACTED PATH THROUGH THE ATMOSPHERE

I	ALTITUDE FROM (KM)	THETA (DEG)	CRANGE (KM)	RANGE (KM)	DBETA (DEG)	BETA (DEG)	PHI (DEG)	DBEND (DEG)	TSAR (K)	PBAR (MB)	BEND (DEG)	PHI (DEG)	RHOBAR (MOL CM-3)
1	2.300	67.700	.264	.264	.032	.002	112.302	.000	252.860	694.394	.000	112.302	1.96E+19
2	3.000	57.658	2.634	2.898	.032	.024	112.331	.003	250.240	636.356	.004	112.331	1.84E+19

H1 TO H2

13 109.000 .000 210.000 .000
CALCULATION OF THE REFRACTED PATH THROUGH THE ATMOSPHERE

I	ALITUDE FRON (KM)	TO (KM)	THETA (DEG)	CRANGE (KM)	RANGE (KM)	DBETA (DEG)	BETA (DEG)	PHI (DEG)	EBEND (DEG)	BENDINC (DEG)	PBAR (MB)	TSAR (K)	RHOJAR (MOL CM-3)
		H1 TO H2											
1	2.300	3.000	67.700	.264	.264	-.322	-.002	112.302	.000	.000	694.394	252.860	1.98E+19
2	2.300	4.000	57.688	2.634	2.898	-.322	.024	112.331	.003	.004	636.356	250.240	1.84E+19

Table 4a. Sample Input and Output - Case 1 (Contd)

INTEGRATED ABSORBER AMOUNTS BY LAYER												
I LAYER BOUNDARIES												
FRGM	TO	AIR	H2O	CO2	O3	CO	CH4	O2				
1	3.000	5.166E+23	6.091E+20	1.703E+20	1.419E+16	1.455E+16	8.259E+17	1.075E+23				
2	4.000	4.045E+24	4.701E+21	1.598E+21	1.454E+17	1.356E+18	3.631E+17	7.747E+18	1.014E+24			
3	5.000	4.315E+24	2.575E+21	1.425E+21	1.191E+17	1.209E+18	3.238E+17	6.908E+18	9.046E+23			
4	6.000	1.595E+24	6.121E+20	5.262E+20	6.258E+16	4.465E+17	1.196E+17	2.551E+18	2.341E+23			
5	7.000	2.257E+24	6.452E+20	7.450E+20	9.581E+16	6.321E+17	1.692E+17	3.613E+18	4.730E+23			
6	8.000	3.425E+24	6.887E+20	1.130E+21	1.565E+17	9.590E+17	2.569E+17	5.481E+18	7.177E+23			
7	9.000	1.865E+24	1.633E+20	1.135E+20	1.508E+17	5.223E+17	1.399E+17	2.985E+18	3.908E+23			
8	10.000	1.169E+24	5.309E+19	3.858E+20	1.315E+17	3.273E+17	6.768E+16	1.870E+18	2.449E+23			
9	11.000	2.658E+24	8.457E+19	8.772E+20	4.005E+17	7.443E+17	1.994E+17	4.253E+18	5.569E+23			
10	12.000	2.882E+24	6.092E+19	7.554E+20	6.490E+17	6.408E+17	1.717E+17	3.663E+18	4.796E+23			
11	13.000	1.954E+24	4.027E+19	6.451E+20	9.140E+17	5.474E+17	1.465E+17	3.128E+18	4.095E+23			
12	14.000	1.635E+24	2.767E+19	5.58E+20	3.203E+18	4.574E+17	1.292E+17	2.531E+18	3.405E+23			
13	15.000	1.635E+24	2.767E+19	5.58E+20	3.203E+18	4.574E+17	1.292E+17	2.531E+18	3.405E+23			
14	16.000	1.635E+24	2.767E+19	5.58E+20	3.203E+18	4.574E+17	1.292E+17	2.531E+18	3.405E+23			
15	17.000	1.635E+24	2.767E+19	5.58E+20	3.203E+18	4.574E+17	1.292E+17	2.531E+18	3.405E+23			
16	18.000	1.635E+24	2.767E+19	5.58E+20	3.203E+18	4.574E+17	1.292E+17	2.531E+18	3.405E+23			
17	19.000	1.635E+24	2.767E+19	5.58E+20	3.203E+18	4.574E+17	1.292E+17	2.531E+18	3.405E+23			
18	20.000	1.635E+24	2.767E+19	5.58E+20	3.203E+18	4.574E+17	1.292E+17	2.531E+18	3.405E+23			
19	21.000	1.635E+24	2.767E+19	5.58E+20	3.203E+18	4.574E+17	1.292E+17	2.531E+18	3.405E+23			
20	22.000	1.635E+24	2.767E+19	5.58E+20	3.203E+18	4.574E+17	1.292E+17	2.531E+18	3.405E+23			
21	23.000	1.635E+24	2.767E+19	5.58E+20	3.203E+18	4.574E+17	1.292E+17	2.531E+18	3.405E+23			
22	24.000	1.635E+24	2.767E+19	5.58E+20	3.203E+18	4.574E+17	1.292E+17	2.531E+18	3.405E+23			
23	25.000	1.635E+24	2.767E+19	5.58E+20	3.203E+18	4.574E+17	1.292E+17	2.531E+18	3.405E+23			
24	26.000	1.635E+24	2.767E+19	5.58E+20	3.203E+18	4.574E+17	1.292E+17	2.531E+18	3.405E+23			
25	27.000	1.635E+24	2.767E+19	5.58E+20	3.203E+18	4.574E+17	1.292E+17	2.531E+18	3.405E+23			
26	28.000	1.635E+24	2.767E+19	5.58E+20	3.203E+18	4.574E+17	1.292E+17	2.531E+18	3.405E+23			
27	29.000	1.635E+24	2.767E+19	5.58E+20	3.203E+18	4.574E+17	1.292E+17	2.531E+18	3.405E+23			
28	30.000	1.635E+24	2.767E+19	5.58E+20	3.203E+18	4.574E+17	1.292E+17	2.531E+18	3.405E+23			
29	31.000	1.635E+24	2.767E+19	5.58E+20	3.203E+18	4.574E+17	1.292E+17	2.531E+18	3.405E+23			
30	32.000	1.635E+24	2.767E+19	5.58E+20	3.203E+18	4.574E+17	1.292E+17	2.531E+18	3.405E+23			
31	33.000	1.635E+24	2.767E+19	5.58E+20	3.203E+18	4.574E+17	1.292E+17	2.531E+18	3.405E+23			
32	34.000	1.635E+24	2.767E+19	5.58E+20	3.203E+18	4.574E+17	1.292E+17	2.531E+18	3.405E+23			
33	35.000	1.635E+24	2.767E+19	5.58E+20	3.203E+18	4.574E+17	1.292E+17	2.531E+18	3.405E+23			
34	36.000	1.635E+24	2.767E+19	5.58E+20	3.203E+18	4.574E+17	1.292E+17	2.531E+18	3.405E+23			
35	37.000	1.635E+24	2.767E+19	5.58E+20	3.203E+18	4.574E+17	1.292E+17	2.531E+18	3.405E+23			
36	38.000	1.635E+24	2.767E+19	5.58E+20	3.203E+18	4.574E+17	1.292E+17	2.531E+18	3.405E+23			
37	39.000	1.635E+24	2.767E+19	5.58E+20	3.203E+18	4.574E+17	1.292E+17	2.531E+18	3.405E+23			
38	40.000	1.635E+24	2.767E+19	5.58E+20	3.203E+18	4.574E+17	1.292E+17	2.531E+18	3.405E+23			
39	41.000	1.635E+24	2.767E+19	5.58E+20	3.203E+18	4.574E+17	1.292E+17	2.531E+18	3.405E+23			
40	42.000	1.635E+24	2.767E+19	5.58E+20	3.203E+18	4.574E+17	1.292E+17	2.531E+18	3.405E+23			

Table 4a. Sample Input and Output - Case 1 (Contd)

13	12.000	1.528E+23	2.232E+18	5.045E+19	1.418E+17	4.279E+16	1.146E+16	2.446E+17	3.202E+22
14	12.100	1.272E+24	1.678E+19	4.200E+20	1.334E+18	3.563E+17	9.546E+16	2.035E+18	2.666E+23
15	13.000	1.217E+24	1.189E+19	4.018E+20	1.573E+18	3.410E+17	9.134E+16	1.948E+18	2.551E+23
16	14.000	1.040E+24	7.632E+18	3.431E+20	1.717E+18	2.912E+17	7.800E+16	1.664E+18	2.179E+23
17	15.000	8.890E+23	6.088E+18	2.934E+20	1.925E+18	2.490E+17	6.670E+16	1.423E+18	1.863E+23
18	16.000	3.954E+23	2.697E+18	1.305E+20	1.014E+18	1.108E+17	2.967E+16	6.328E+17	8.287E+22
19	16.500	3.659E+23	2.521E+18	1.208E+20	1.013E+18	1.025E+17	2.745E+16	5.856E+17	7.688E+22
20	17.000	18.000	6.515E+23	4.608E+18	2.151E+20	2.025E+18	1.825E+17	4.868E+16	1.043E+18
21	18.000	19.000	5.574E+23	4.304E+18	1.840E+20	1.901E+18	1.561E+17	4.181E+16	8.922E+17
22	19.000	20.000	4.768E+23	4.081E+18	1.574E+20	1.691E+18	1.235E+17	3.577E+16	7.932E+17
23	20.000	21.000	4.076E+23	4.161E+18	1.345E+20	1.742E+18	1.142E+17	3.058E+16	6.524E+17
24	21.000	22.000	3.482E+23	4.422E+18	1.149E+20	1.594E+18	9.752E+16	2.612E+16	5.573E+17
25	22.000	23.000	2.975E+23	4.549E+18	8.200E+19	1.462E+18	8.330E+16	2.232E+16	4.761E+17
26	23.000	24.000	2.540E+23	4.931E+18	8.385E+19	1.290E+18	7.113E+16	1.906E+16	4.666E+17
27	24.000	25.000	2.168E+23	5.486E+18	7.156E+19	1.033E+18	6.072E+16	1.625E+16	3.470E+17
28	25.000	26.000	1.874E+23	4.930E+18	5.525E+19	8.733E+17	4.688E+16	1.256E+16	2.678E+17
29	30.000	30.000	5.150E+23	1.663E+19	1.700E+20	2.760E+18	1.442E+17	3.863E+16	8.241E+17
30	30.000	33.000	2.094E+23	6.645E+18	6.911E+19	1.258E+18	5.864E+16	1.571E+16	3.351E+17
31	33.000	35.000	9.271E+22	2.415E+18	3.060E+19	6.544E+17	2.597E+16	6.958E+15	1.484E+17
32	35.000	40.000	1.352E+23	3.051E+18	4.464E+19	1.013E+18	3.788E+16	1.015E+16	2.165E+17
33	40.000	41.400	2.220E+22	4.590E+17	7.357E+18	1.571E+17	6.243E+15	1.672E+15	3.568E+16
34	41.400	45.000	3.968E+22	7.925E+17	1.310E+19	2.325E+17	1.112E+16	2.977E+15	6.352E+16
35	45.000	49.400	2.704E+22	4.537E+17	8.925E+18	1.164E+17	7.574E+15	2.029E+15	4.329E+16
36	49.400	50.000	2.533E+21	3.420E+16	8.361E+17	8.763E+15	7.094E+14	1.900E+14	4.055E+15
37	50.000	70.000	2.362E+22	2.727E+17	9.447E+18	6.814E+16	8.016E+15	2.147E+15	4.581E+16
38	70.000	77.300	1.272E+21	4.936E+15	4.204E+17	8.914E+14	3.567E+14	9.554E+13	2.038E+15
39	77.300	98.700	5.617E+20	2.042E+15	1.858E+17	1.645E+14	1.576E+14	4.222E+13	9.007E+14
40	98.700	100.000	3.631E+18	1.179E+13	1.199E+15	2.021E+11	1.017E+12	2.725E+11	5.813E+12
OTOTAL	2.900	100.000	3.834E+25	1.036E+22	2.265E+22	3.307E+19	1.074E+19	2.876E+18	6.136E+19

1 SUMMARY OF THE GEOMETRY CALCULATION

MODEL = SUBARCTIC WINTER
H1 = 2.900 KM
H2 = 100.000 KZ
ANGLE = 57.700 DEG
RANGE = 245.627 KM
BETA = 2.017 DEG
PHI = 114.288 DEG
HMIN = 2.900 KM
BENDING = .029 DEG
LEN = 0

AIRMS = 1.78 RELATIVE TO A VERTICAL PATH, GROUND TO SPACE

FINAL SET OF LAYERS FOR INPUT TO FASCOD1

A LAYER AMOUNT MAY BE SET TO ZERO IF THE CUMULATIVE AMOUNT FOR THAT LAYER AND ABOVE IS LESS THAN 0.1 PERCENT OF THE TOTAL AMOUNT. THIS IS DONE ONLY FOR THE FOLLOWING CASES

1. IEMIT = 0 (TRANSMITTANCE)
2. IEMIT = 1 (RADIANCE) AND ICNTRL = 3 (PATH LOOKING UP)

O2 IS NOT INCLUDED
IF THE AMOUNTS FOR ALL THE MOLECULES BUT O2 ARE ZEROED, THE REMAINING LAYERS ARE ELIMINATED

L	LAYER BOUNDARIES FROM (KM)	ICNTRL	PBAR (MB)	TBAR (K)	AIR	H2O	CO2	C3	N2O	CO	CH4	O2

INTEGRATED AMOUNTS (MOLS CM-2)

Table 4a. Sample Input and Output - Case 1 (Contd)

1	2.500	5.400	3	589.04	246.59	1.13E+25	8.50E+21	3.72E+21	3.74E+17	3.16E+18	8.45E+17	1.80E+19	2.36E+24
2	5.400	7.600	3	419.36	231.02	7.55E+24	1.48E+21	2.49E+21	4.42E+17	2.11E+18	5.66E+17	1.21E+19	1.56E+24
3	7.600	12.100	3	262.80	218.23	9.89E+24	2.68E+20	3.26E+21	3.44E+18	2.77E+18	7.42E+17	1.58E+19	2.07E+24
4	12.100	16.500	3	130.55	217.08	4.81E+24	4.51E+19	1.59E+21	7.57E+18	1.35E+18	3.61E+17	7.70E+13	1.01E+24
5	16.500	21.000	3	64.98	215.09	2.46E+24	1.97E+19	8.12E+20	8.66E+18	6.89E+17	1.84E+17	3.94E+13	5.15E+23
6	21.000	25.900	3	31.15	212.41	1.28E+24	2.43E+19	4.24E+20	6.31E+18	3.60E+17	9.63E+16	2.05E+13	2.69E+23
7	25.900	33.000	3	12.99	214.93	7.24E+23	2.32E+19	2.39E+20	4.02E+18	2.03E+17	5.43E+16	1.16E+13	1.52E+23
8	33.000	41.400	3	4.12	225.88	2.50E+23	0.	8.26E+19	1.82E+18	7.01E+16	1.88E+16	4.01E+17	5.24E+22
9	41.400	49.400	3	1.23	246.06	6.67E+22	0.	2.20E+19	3.49E+17	1.87E+16	5.01E+15	1.07E+17	1.40E+22
10	49.400	77.300	3	.32	254.88	3.24E+22	0.	0.	7.78E+16	0.	0.	0.	6.80E+21

Table 4b. Sample Input and Output - Case 2

*****INPUT CASE 2*****									
7	3					20			
	33.0					94.87			
	820.0	830.0							
	2.0	50.0				50.0			
36									
S	7C + TRACE GASES								
	0.0000	1012.2500				288.1500			
	.100E+05	.322E+03				.320E+00	.150E+00	.170E+01	.209E+06 .300E-03
	.300E-03	.300E-03				.300E-04	.440E-07	.100E-07	.100E-03 .170E-05
	.300E-05	.100E-06				.600E-03	.240E-02		
	2.0000	795.0100				275.1540			
	.970E+04	.322E+03				.330E-01	.320E+00	.170E+01	.209E+06 .300E-03
	.250E-03	.300E-03				.120E-02	.400E-04	.100E-07	.650E-04 .170E-05
	.300E-05	.100E-06				.580E-03	.300E-03		
	4.0000	616.6000				262.1660			
	.380E+04	.322E+03				.340E-01	.320E+00	.170E+01	.209E+06 .300E-03
	.140E-03	.300E-03				.100E-02	.500E-04	.300E-07	.330E-04 .170E-05
	.300E-05	.100E-06				.560E-03	.130E-03		
	6.0000	472.1700				249.1870			
	.150E+04	.322E+03				.410E-01	.320E+00	.170E+01	.209E+06 .300E-03
	.950E-04	.300E-03				.850E-03	.700E-04	.900E-07	.260E-04 .170E-05
	.300E-05	.120E-06				.550E-03	.700E-04		
	8.0000	356.5100				236.2150			
	.650E+03	.322E+03				.600E-01	.320E+00	.160E+01	.209E+06 .300E-03
	.700E-04	.300E-03				.700E-03	.800E-04	.230E-06	.220E-04 .170E-05
	.300E-05	.150E-06				.530E-03	.500E-04		
	10.0000	264.9900				223.2520			
	.200E+02	.322E+03				.130E+00	.320E+00	.160E+01	.209E+06 .300E-03
	.600E-04	.300E-03				.550E-03	.900E-04	.470E-07	.600E-06 .240E-04 .170E-05
	.300E-05	.200E-06				.520E-03	.340E-04		
	12.0000	193.9900				216.6500			
	.600E+01	.322E+03				.310E+00	.310E+00	.160E+01	.209E+06 .300E-03
	.500E-04	.300E-03				.400E-03	.100E-03	.490E-07	.300E-04 .170E-05
	.500E-05	.400E-06				.500E-03	.330E-04		
	14.0000	141.7000				216.6500			
	.290E+01	.322E+03				.500E+00	.300E+00	.150E+01	.209E+06 .300E-03
	.560E-04	.300E-03				.300E-03	.200E-03	.450E-05	.100E-04 .170E-05
	.300E-05	.700E-06				.470E-03	.370E-04		
	16.0000	103.5200				216.6500			
	.220E+01	.322E+03				.850E+00	.290E+00	.150E+01	.209E+06 .270E-03
	.600E-04	.350E-03				.100E-03	.300E-03	.810E-07	.250E-03 .170E-05
	.300E-05	.130E-05				.390E-03	.360E-04		
	18.0000	75.6520				216.6500			
	.340E+01	.322E+03				.160E+01	.270E+00	.140E+01	.209E+06 .230E-03
	.500E-04	.400E-03				.100E-04	.130E-06	.250E-04	.400E-03 .170E-05
	.300E-05	.250E-05				.310E-03	.340E-04		
	20.0000	55.2930				216.6500			
	.350E+01	.322E+03				.260E+01	.240E+00	.130E+01	.209E+06 .250E-03
	.310E-04	.900E-03				.100E-05	.200E-02	.190E-06	.600E-04 .500E-03 .170E-05
	.300E-05	.600E-05				.240E-03	.330E-04		
	22.0000	40.4750				218.5740			

Table 4b. Sample Input and Output - Case 2 (Contd)

.350E+01	.322E+03	.360E+01	.200E+00	.160E-01	.110E+01	.209E+06	.300E-03
.220E-04	.120E-02	.100E-06	.300E-02	.520E-06	.100E-03	.550E-03	.170E-05
.300E-05	.100E-04	.90E-03	.400E-04				
24.0000	29.7170	220.5600					
.350E+01	.322E+03	.470E+01	.160E+00	.170E-01	.100E+01	.209E+06	.400E-03
.190E-04	.220E-02	.100E-06	.400E-02	.100E-05	.150E-03	.600E-03	.170E-05
.300E-05	.200E-04	.140F-03	.500E-04				
26.0000	21.8830	222.5440					
.370E+01	.322E+03	.570E+01	.130E+00	.180E-01	.930E+00	.209E+06	.800E-03
.170E-04	.310E-02	.100E-06	.350E-02	.290E-05	.200E-03	.650E-03	.170E-05
.300E-05	.500E-04	.110E-03	.600E-04				
23.0000	16.1610	224.5270					
.390E+01	.322E+03	.620E+01	.110E+00	.190E-01	.860E+00	.209E+06	.150E-02
.150E-04	.450E-02	.100E-06	.300E-02	.610E-05	.250E-03	.700E-03	.170E-05
.300E-05	.100E-03	.700E-04	.800E-04				
30.0000	11.9700	226.5050					
.410E-01	.322E+03	.660E+01	.900E-01	.200E-01	.800E+00	.209E+06	.250E-02
.130E-04	.750E-02	.100E-06	.200E-02	.100E-04	.300E-03	.100E-02	.180E-05
.300E-05	.200E-03	.300E-04	.900E-04				
32.0000	8.6910	228.4900					
.420E+01	.322E+03	.720E+01	.700E-01	.220E-01	.730E+00	.209E+06	.400E-02
.120E-04	.700E-02	.100E-06	.100E-02	.280E-04	.320E-03	.120E-02	.210E-05
.300E-05	.400E-03	.170E-04	.100E-03				
34.0000	6.6340	233.7430					
.430E+01	.322E+03	.770E+01	.500E-01	.240E-01	.660E+00	.209E+06	.700E-02
.110E-04	.550E-02	.100E-06	.600E-03	.580E-04	.340E-03	.160E-02	.240E-05
.300E-05	.500E-03	.600E-05	.110E-03				
36.0000	4.9950	239.2820					
.440E+01	.322E+03	.810E+01	.320E-01	.270E-01	.570E+00	.209E+06	.300E-02
.110E-04	.500E-02	.100E-06	.350E-03	.130E-03	.360E-03	.180E-02	.310E-05
.300E-05	.600E-03	.250E-05	.120E-03				
38.0000	3.7710	244.8180					
.440E+01	.322E+03	.780E+01	.220E-01	.300E-01	.480E+00	.209E+06	.100E-01
.120E-04	.450E-02	.100E-06	.200E-03	.220E-03	.380E-03	.170E-02	.390E-05
.300E-05	.700E-03	.100E-05	.120E-03				
40.0000	2.8710	250.3500					
.450E+01	.322E+03	.730E+01	.160E-01	.300E-01	.400E+00	.209E+06	.120E-01
.130E-04	.350E-02	.100E-06	.100E-03	.310E-03	.400E-03	.150E-02	.510E-05
.300E-05	.720E-03	.500E-06	.110E-03				
42.0000	2.1200	255.8780					
.450E+01	.322E+03	.640E+01	.100E-01	.300E-01	.320E+00	.209E+06	.110E-01
.150E-04	.300E-02	.100E-06	.700E-04	.400E-03	.410E-03	.140E-02	.640E-05
.300E-05	.600E-03	.200E-06	.950E-04				
44.0000	1.6950	261.4030					
.450E+01	.322E+03	.580E+01	.700E-02	.300E-01	.250E+00	.209E+06	.100E-01
.180E-04	.250E-02	.100E-06	.400E-04	.500E-03	.420E-03	.130E-02	.700E-05
.300E-05	.300E-03	.800E-07	.800E-04				
46.0000	1.3130	266.9250					
.460E+01	.322E+03	.470E+01	.400E-02	.300E-01	.200E+00	.209E+06	.100E-01
.230E-04	.200E-02	.100E-06	.200E-04	.600E-03	.430E-03	.130E-02	.730E-05
.300E-05	.170E-03	.250E-07	.650E-04				
48.0000	1.6220	270.6500					
.480E+01	.322E+03	.380E+01	.200E-02	.300E-01	.150E+00	.209E+06	.100E-01
.310E-04	.150E-02	.100E-06	.100E-04	.700E-03	.440E-03	.130E-02	.740E-05
.300E-05	.130E-03	.100E-07	.510E-04				

Table 4b. Sample Input and Output - Case 2 (Contd)

[illegible]

```
*****OUTPUT CASE 2*****
*****PROGRAM FSCATM*****      01/11/83      11.03.37.
*****
```

CONTROL CARD 1: MODEL AND OPTIONS

MODEL 7300W

Table 4b. Sample Input and Output - Case 2 (Contd)

ITYPE = 3
 IEND = 0
 NOZERO = 0
 NOPRNT = 0
 KMAX = 20
 IPUNCH = 0
 RE = 0.000 KM

CONTROL CARD 1 PARAMETERS WITH DEFAULTS:

MODEL = 7
 IITYPE = 3
 IEND = 0
 NOZERO = 0
 NOPRNT = 0
 KMAX = 20
 IPUNCH = 0
 RE = 6371.230 KM

SLANT PATH SELECTED, IITYPE = 3

CONTROL CARD 2: SLANT PATH PARAMETERS

H1 = 33.0000 KM
 H2 = 0.0000 KM
 ANGLE = 94.8700 DEG
 RANGE = 0.0000 KM
 BETA = 0.0000 DEG
 LEN = 0

CONTROL CARD 3

V1 = 820.000 CM-1
 V2 = 830.000 CM-1
 VBAR = 825.000 CM-1

AUTOLAYERING SELECTED

AVTRAT = 2.00
 TDIFF1 = 50.00
 TDIFF2 = 50.00

READING IN USER SUPPLIED MODEL ATMOSPHERE

Table 4b. Sample Input and Output - Case 2 (Contd)

IMOD = 36 PROFILE = US 76 + TRACE GASES												
I	Z (KM)	P (MB)	T (K)	TD (C)	RH (PERCENT)	PPH2O (MB)	DENH2O (GM M-3)	AMSMIX (G/G)				
VOL MIX (PPMV)	RAT	H2O	CO2	O3	N2O	CH4	O2	NO				
		SO2	NO2	NH3	HNO3	HF	HCL	HBR				
		HI	CLO	OCS	H2CO							
1	0.000	1013.250	288.150	-0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1.000E+04	3.220E+02	3.300E-02	3.200E-01	1.500E-01	1.700E+00	2.050E+05	3.000E-04	3.000E-04	3.000E-04	3.000E-04	3.000E-04	3.000E-04
3.000E-04	3.000E-04	1.300E-03	3.000E-05	4.400E-08	1.000E-08	1.000E-04	1.000E-04	1.700E-06	1.000E-04	1.000E-04	1.700E-06	1.700E-06
3.000E-06	1.000E-07	6.000E-04	2.400E-03									
2	2.000	795.010	275.154	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
9.700E+03	3.220E+02	3.300E-02	3.200E-01	1.400E-01	1.700E+00	2.090E+05	3.000E-04	3.000E-04	3.000E-04	3.000E-04	3.000E-04	3.000E-04
2.500E-04	3.000E-04	1.200E-03	4.000E-05	4.400E-08	1.000E-08	1.000E-04	1.000E-04	1.700E-06	1.000E-04	1.000E-04	1.700E-06	1.700E-06
3.000E-06	1.000E-07	5.800E-04	3.000E-04									
3	4.000	616.600	262.166	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
3.800E+03	3.220E+02	3.400E-02	3.200E-01	1.300E-01	1.700E+00	2.090E+05	3.000E-04	3.000E-04	3.000E-04	3.000E-04	3.000E-04	3.000E-04
1.400E-04	3.000E-04	1.000E-03	5.000E-05	4.400E-08	3.000E-08	3.000E-05	3.000E-05	1.700E-06	3.000E-05	3.000E-05	1.700E-06	1.700E-06
3.000E-06	1.000E-07	5.600E-04	1.300E-04									
4	6.000	472.170	249.187	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1.500E+03	3.220E+02	4.100E-02	3.200E-01	1.300E-01	1.700E+00	2.090E+05	3.000E-04	3.000E-04	3.000E-04	3.000E-04	3.000E-04	3.000E-04
9.500E-05	3.000E-04	3.500E-04	7.000E-05	4.400E-08	9.000E-08	2.600E-05	2.600E-05	1.700E-06	9.000E-08	9.000E-08	1.700E-06	1.700E-06
3.000E-06	1.200E-07	5.500E-04	7.000E-05									
5	8.000	356.510	236.215	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
6.500E+02	3.220E+02	6.000E-02	3.200E-01	1.200E-01	1.600E+00	2.090E+05	3.000E-04	3.000E-04	3.000E-04	3.000E-04	3.000E-04	3.000E-04
7.000E-05	3.000E-04	7.000E-04	8.000E-05	4.400E-08	2.300E-07	2.200E-05	2.200E-05	1.700E-06	2.300E-07	2.300E-07	1.700E-06	1.700E-06
3.000E-06	1.500E-07	5.300E-04	5.000E-05									
6	10.000	264.990	223.252	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
2.000E+01	3.220E+02	1.300E-01	3.200E-01	1.000E-01	1.600E+00	2.090E+05	3.000E-04	3.000E-04	3.000E-04	3.000E-04	3.000E-04	3.000E-04

Table 4b. Sample Input and Output - Case 2 (Contd)

6.000E-05	3.000E-04	5.500E-04	9.000E-05	4.700E-08	6.000E-07	2.400E-05	1.700E-06
3.000E-06	2.000E-07	5.200E-04	3.400E-05				
7	12.000	193.590	216.550	0.000	0.000	0.000	0.000
6.000E+00	3.220E+02	3.100E-01	3.100E-01	8.000E-02	1.600E+00	2.090E+05	3.000E-04
5.500E-05	3.000E-04	4.000E-04	1.000E-04	4.900E-08	2.000E-06	3.000E-05	1.700E-06
3.000E-06	4.000E-07	5.000E-04	3.300E-05				
8	14.000	141.700	216.650	0.000	0.000	0.000	0.000
2.900E+00	3.220E+02	5.000E-01	3.000E-01	5.000E-02	1.500E+00	2.090E+05	3.000E-04
5.600E-05	3.300E-04	3.000E-04	2.000E-04	5.300E-08	4.500E-06	1.000E-05	1.700E-06
3.000E-06	7.000E-07	4.700E-04	3.700E-05				
9	16.000	103.520	216.650	0.000	0.000	0.000	0.000
3.200E+00	3.220E+02	8.500E-01	2.900E-01	3.000E-02	1.500E+00	2.090E+05	2.700E-04
6.000E-05	3.500E-04	1.000E-04	3.000E-04	8.100E-08	1.000E-05	2.500E-04	1.700E-06
3.000E-06	1.300E-06	3.900E-04	3.600E-05				
10	18.000	75.652	216.650	0.000	0.000	0.000	0.000
3.400E+00	3.220E+02	1.600E+00	2.700E-01	2.000E-02	1.400E+00	2.090E+05	2.300E-04
5.000E-05	4.000E-04	1.000E-05	1.100E-03	1.300E-07	2.500E-05	4.000E-04	1.700E-06
3.000E-06	2.500E-06	3.100E-04	3.400E-05				
11	20.000	55.293	216.650	0.000	0.000	0.000	0.000
3.500E+00	3.220E+02	2.600E+00	2.400E-01	1.500E-02	1.300E+00	2.090E+05	2.500E-04
3.100E-05	9.000E-04	1.000E-06	2.000E-03	1.300E-07	6.000E-05	5.000E-04	1.700E-06
3.000E-06	6.000E-06	2.400E-04	3.300E-05				
12	22.000	40.475	218.574	0.000	0.000	0.000	0.000
3.500E+00	3.220E+02	3.600E+00	2.000E-01	1.800E-02	1.100E+00	2.090E+05	3.000E-04
2.200E-05	1.200E-03	1.000E-07	3.000E-03	5.200E-07	1.000E-04	5.500E-04	1.700E-06
3.000E-06	1.000E-05	1.900E-04	4.000E-05				
13	24.000	29.717	220.560	0.000	0.000	0.000	0.000

Table 4b. Sample Input and Output - Case 2 (Contd)

3.500E+00	3.220E+02	4.700E+00	1.600E-01	1.700E-02	1.000E+00	2.050E+05	4.000E-04
1.900E-05	2.200E-03	1.000E-07	4.000E-03	1.000E-06	1.500E-04	6.000E-04	1.700E-06
3.000E-06	2.000E-05	1.400E-04	5.000E-05				
14	26.000	21.883	222.544	0.000	0.000	0.000	0.000
3.700E+00	3.220E+02	5.700E+00	1.300E-01	1.800E-02	9.300E-01	2.090E+05	8.000E-04
1.700E-05	3.100E-03	1.000E-07	3.500E-03	2.900E-06	2.000E-04	6.500E-04	1.700E-06
3.000E-06	5.000E-05	1.100E-04	6.000E-05				
15	28.000	16.161	224.527	0.000	0.000	0.000	0.000
3.900E+00	3.220E+02	6.200E+00	1.100E-01	1.900E-02	8.600E-01	2.090E+05	1.500E-03
1.500E-05	4.500E-03	1.000E-07	3.000E-03	6.100E-06	2.500E-04	7.000E-04	1.700E-06
3.000E-06	1.000E-04	7.000E-05	8.000E-05				
16	30.000	11.970	226.509	0.000	0.000	0.000	0.000
4.100E+00	3.220E+02	6.500E+00	9.000E-02	2.000E-02	8.000E-01	2.090E+05	2.500E-03
1.300E-05	7.500E-03	1.000E-07	2.300E-03	1.000E-05	3.000E-04	1.000E-03	1.800E-06
3.000E-06	2.000E-04	3.000E-05	9.000E-05				
17	32.000	8.891	228.490	0.000	0.000	0.000	0.000
4.200E+00	3.220E+02	7.200E+00	7.000E-02	2.200E-02	7.300E-01	2.090E+05	4.000E-03
1.200E-05	7.000E-03	1.000E-07	1.900E-03	2.800E-05	3.200E-04	1.200E-03	2.100E-06
3.000E-06	4.000E-04	1.700E-05	1.000E-04				
18	34.000	6.634	233.743	0.000	0.000	0.000	0.000
4.300E+00	3.220E+02	7.700E+00	5.000E-02	2.400E-02	6.600E-01	2.090E+05	7.000E-03
1.100E-05	5.500E-03	1.000E-07	6.000E-04	5.800E-05	3.400E-04	1.600E-03	2.400E-06
3.000E-06	5.000E-04	6.000E-06	1.100E-04				
19	36.000	4.985	239.282	0.000	0.000	0.000	0.000
4.400E+00	3.220E+02	8.100E+00	3.200E-02	2.700E-02	5.700E-01	2.090E+05	9.000E-03
1.100E-05	5.000E-03	1.000E-07	3.500E-04	1.300E-04	3.600E-04	1.800E-03	3.100E-06
3.000E-06	6.000E-04	2.500E-06	1.200E-04				
20	38.000	3.771	244.818	0.000	0.000	0.000	0.000

Table 4b. Sample Input and Output - Case 2 (Contd)

4.400E+00	3.220E+02	7.800E+00	2.200E-02	3.000E-02	4.800E-01	2.050E+05	1.000E-02
1.200E-05	4.500E-03	1.000E-07	2.000E-04	2.200E-04	3.800E-04	1.700E-03	3.900E-06
3.000E-06	7.000E-04	1.000E-06	1.200E-04				
21	40.000	2.871	250.350	0.000	0.000	0.000	0.000
4.500E+00	3.220E+02	7.300E+00	1.600E-02	3.000E-02	4.000E-01	2.090E+05	1.200E-02
1.300E-05	3.500E-03	1.000E-07	1.000E-04	3.100E-04	4.000E-04	1.500E-03	5.100E-06
3.000E-06	7.200E-04	5.000E-07	1.100E-04				
22	42.000	2.120	255.878	0.000	0.000	0.000	0.000
4.500E+00	3.220E+02	6.400E+00	1.000E-02	3.000E-02	3.200E-01	2.090E+05	1.100E-02
1.500E-05	3.000E-03	1.000E-07	7.000E-05	4.000E-04	4.100E-04	1.400E-03	6.400E-06
3.000E-06	6.000E-04	2.300E-07	9.500E-05				
23	44.000	1.695	261.403	0.000	0.000	0.000	0.000
4.500E+00	3.220E+02	5.800E+00	7.000E-03	3.000E-02	2.500E-01	2.090E+05	1.000E-02
1.300E-05	2.500E-03	1.000E-07	4.000E-05	5.000E-04	4.200E-04	1.300E-03	7.000E-06
3.000E-06	3.000E-04	8.000E-08	8.000E-05				
24	46.000	1.313	266.925	0.000	0.000	0.000	0.000
4.600E+00	3.220E+02	4.700E+00	4.000E-03	3.000E-02	2.000E-01	2.090E+05	1.000E-02
2.300E-05	2.000E-03	1.000E-07	2.000E-05	6.000E-04	4.300E-04	1.300E-03	7.300E-06
3.000E-06	1.700E-04	2.500E-08	6.500E-05				
25	48.000	1.023	270.650	0.000	0.000	0.000	0.000
4.800E+00	3.220E+02	3.800E+00	2.000E-02	3.000E-02	1.500E-01	2.090E+05	1.000E-02
3.100E-05	1.500E-03	1.000E-07	1.000E-05	7.000E-04	4.400E-04	1.300E-03	7.400E-06
3.000E-06	1.300E-04	1.000E-08	5.100E-05				
26	50.000	.798	270.650	0.000	0.000	0.000	0.000
5.000E+00	3.220E+02	3.100E+00	1.000E-03	3.000E-02	1.000E-01	2.090E+05	1.000E-02
3.500E-05	1.000E-03	1.000E-07	5.000E-06	8.000E-04	4.500E-04	1.300E-03	7.400E-06
3.000E-06	1.000E-04	1.000E-08	4.000E-05				

Table 4b. Sample Input and Output - Case 2 (Contd)

27	55.000	.425	250.771	0.000	0.000	0.000	0.000	0.000	0.000
	5.000E+00	0.	0.	0.	0.	0.	0.	0.	0.
	0.	0.	0.	0.	0.	0.	0.	0.	0.
	0.	0.	0.	0.	0.	0.	0.	0.	0.
28	60.000	.220	247.321	0.000	0.000	0.000	0.000	0.000	0.000
	5.000E+00	0.	0.	0.	0.	0.	0.	0.	0.
	0.	0.	0.	0.	0.	0.	0.	0.	0.
	0.	0.	0.	0.	0.	0.	0.	0.	0.
29	65.000	.109	233.292	0.000	0.000	0.000	0.000	0.000	0.000
	5.000E+00	0.	0.	0.	0.	0.	0.	0.	0.
	0.	0.	0.	0.	0.	0.	0.	0.	0.
	0.	0.	0.	0.	0.	0.	0.	0.	0.
30	70.000	.052	219.585	0.000	0.000	0.000	0.000	0.000	0.000
	5.000E+00	0.	0.	0.	0.	0.	0.	0.	0.
	0.	0.	0.	0.	0.	0.	0.	0.	0.
	0.	0.	0.	0.	0.	0.	0.	0.	0.
31	75.000	.024	208.399	0.000	0.000	0.000	0.000	0.000	0.000
	5.000E+00	0.	0.	0.	0.	0.	0.	0.	0.
	0.	0.	0.	0.	0.	0.	0.	0.	0.
	0.	0.	0.	0.	0.	0.	0.	0.	0.
32	80.000	.011	198.639	0.000	0.000	0.000	0.000	0.000	0.000
	5.000E+00	0.	0.	0.	0.	0.	0.	0.	0.
	0.	0.	0.	0.	0.	0.	0.	0.	0.
	0.	0.	0.	0.	0.	0.	0.	0.	0.
33	85.000	.005	188.893	0.000	0.000	0.000	0.000	0.000	0.000
	5.000E+00	0.	0.	0.	0.	0.	0.	0.	0.
	0.	0.	0.	0.	0.	0.	0.	0.	0.
	0.	0.	0.	0.	0.	0.	0.	0.	0.

Table 4b. Sample Input and Output - Case 2 (Contd)

1 ATMOSPHERIC PROFILE SELECTED IS: M = 7 US 76 + TRACE GASES																
I	Z (KM)	P (MB)	T (K)	REFRACT INDEX-1 *1.065	AIR (K)	DENSITY (MOLS CM-3)										NO. HBR
						H2O SO2 H2	C32 NO2 CLO	O3 NH3 OCS	N2O HNO3 H2CO	CO OH	CH4 HF	O2 HCL				
34	90.000	.002	166.873	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000			
	5.000E+00	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.			
	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.			
	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.			
35	95.000	.001	188.420	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000			
	5.000E+00	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.			
	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.			
	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.			
36	100.000	.000	195.080	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000			
	5.000E+00	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.			
	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.			
	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.			
1	0.000	1013.250	288.150	271.956	2.55E+19	2.55E+17	8.20E+15	8.40E+11	8.15E+12	3.82E+12	4.33E+13	5.32E+18	7.64E+09			
						7.64E+09	7.64E+09	3.31E+10	7.64E+08	1.12E+06	2.55E+05	2.55E+09	4.33E+07			
2	2.000	795.010	275.154	223.485	2.09E+19	2.03E+17	6.74E+15	6.91E+11	6.70E+12	2.93E+12	3.56E+13	4.37E+18	6.28E+09			
						5.23E+09	6.28E+09	2.51E+10	8.37E+08	9.21E+05	2.09E+05	1.36E+09	3.56E+07			
3	4.000	616.600	262.166	182.088	1.70E+19	6.47E+16	5.49E+15	5.79E+11	5.45E+12	2.21E+12	2.90E+13	3.56E+18	5.11E+09			
						2.38E+09	3.11E+09	1.70E+10	8.52E+08	7.50E+05	5.11E+05	5.62E+08	2.60E+07			
4	6.000	472.170	249.167	146.750	1.37E+19	2.06E+16	4.42E+15	5.63E+11	4.39E+12	1.78E+12	2.33E+13	2.87E+18	4.12E+09			
						1.30E+09	4.12E+09	1.17E+10	9.61E+08	6.04E+05	1.24E+06	3.57E+08	2.33E+07			
5	8.000	356.510	236.215	116.902	1.09E+19	7.11E+15	3.52E+15	6.56E+11	3.50E+12	1.31E+12	1.75E+13	2.28E+18	3.28E+09			
						7.65E+08	3.28E+09	7.65E+09	8.75E+08	4.81E+05	2.51E+06	2.40E+08	1.86E+07			
6	10.000	264.990	223.252	91.945	8.60E+18	3.28E+07	1.64E+06	5.79E+09	5.47E+08	8.60E+11	1.38E+13	1.80E+18	2.58E+09			
						1.72E+14	2.77E+15	1.12E+12	2.75E+12	8.60E+11	1.38E+13	1.80E+18	2.58E+09			
7	12.000	193.990	216.650	69.361	6.49E+18	2.58E+07	1.72E+06	4.47E+09	2.92E+08	4.04E+05	5.16E+06	2.06E+08	1.46E+07			
						3.89E+13	2.03E+15	2.01E+12	2.07E+12	5.19E+11	1.04E+13	1.36E+18	1.95E+09			
						3.57E+08	1.95E+09	2.55E+09	6.49E+08	3.18E+05	1.30E+07	1.95E+08	1.10E+07			
8	14.000	141.700	216.650	50.665	4.74E+18	1.37E+12	1.53E+15	2.37E+12	1.42E+12	2.37E+11	7.11E+12	9.90E+17	1.42E+09			

Table 4b. Sample Input and Output - Case 2 (Contd).

9	16.000	103.520	216.650	37.014	3.46E+18	2.65E+08	1.56E+09	1.42E+09	9.47E+08	2.51E+05	2.13E+07	4.74E+07	8.05E+06
						1.42E+07	3.32E+05	2.23E+05	1.75E+08				
						1.11E+13	1.11E+15	2.94E+12	1.00E+12	1.04E+11	5.19E+12	7.23E+17	9.34E+08
						2.09E+08	1.21E+09	3.46E+06	1.04E+09	2.80E+05	3.46E+07	3.65E+08	5.88E+06
10	18.000	75.652	216.650	27.049	2.53E+18	1.04E+07	4.50E+06	1.35E+09	1.25E+08	5.06E+10	3.54E+12	5.2E+17	5.82E+08
						8.60E+12	8.14E+14	4.05E+12	6.83E+11	3.29E+05	6.32E+07	1.01E+09	4.30E+06
						1.26E+08	1.01E+09	2.53E+07	2.78E+09	2.77E+10	2.40E+12	3.86E+17	4.62E+08
						7.59E+06	6.32E+06	7.84E+08	8.60E+07	3.51E+05	1.11E+08	3.25E+08	3.14E+06
11	20.000	55.293	216.650	19.770	1.85E+18	6.47E+12	5.95E+14	4.61E+12	4.43E+11	2.15E+10	1.48E+12	2.80E+17	4.02E+08
						5.73E+07	1.66E+09	1.55E+06	3.70E+09	6.97E+05	1.34E+08	7.38E+08	2.28E+06
						5.55E+06	1.11E+07	4.44E+08	6.10E+07	1.28E+10	6.62E+11	1.49E+17	5.70E+08
12	22.000	40.475	218.574	14.344	1.34E+18	4.69E+12	4.32E+14	4.83E+12	2.68E+11	2.07E+06	1.42E+08	4.63E+08	1.21E+06
						2.95E+07	1.61E+09	1.34E+05	4.02E+09	9.91E+09	4.48E+11	1.09E+17	3.90E+08
						4.02E+06	1.34E+07	2.55E+06	5.36E+07	1.66E+10	9.76E+11	2.04E+17	3.90E+08
13	24.000	29.717	220.550	10.437	9.76E+17	3.42E+12	3.14E+14	4.59E+12	1.58E+11	9.76E+05	1.46E+08	5.86E+08	1.66E+06
						1.85E+07	2.15E+09	9.76E+04	3.90E+09	3.18E+06	1.50E+08	3.65E+08	8.66E+05
						2.93E+06	1.95E+07	1.37E+08	4.88E+07	1.28E+10	6.62E+11	1.49E+17	5.70E+08
14	26.000	21.883	222.544	7.617	7.12E+17	2.64E+12	2.29E+14	4.06E+12	9.26E+10	2.07E+06	1.42E+08	4.63E+08	1.21E+06
						1.21E+07	2.21E+09	7.12E+04	2.49E+09	9.91E+09	4.48E+11	1.09E+17	3.90E+08
						2.14E+06	3.56E+07	7.83E+07	4.27E+07	3.18E+06	1.50E+08	3.65E+08	8.66E+05
15	28.000	16.161	224.527	5.576	5.21E+17	2.03E+12	1.68E+14	3.23E+12	5.73E+10	9.91E+09	4.48E+11	1.09E+17	3.90E+08
						7.82E+06	2.35E+09	5.21E+04	1.58E+09	3.18E+06	1.50E+08	3.65E+08	8.66E+05
						1.55E+06	5.21E+07	3.65E+07	4.17E+07	7.66E+09	3.06E+11	3.00E+16	9.57E+08
16	30.000	11.970	226.509	4.094	3.83E+17	1.57E+12	1.23E+14	2.53E+12	3.44E+10	3.83E+06	1.15E+08	3.83E+08	6.89E+05
						4.98E+06	2.87E+09	3.83E+04	7.66E+08	3.83E+06	1.15E+08	3.83E+08	6.89E+05
						1.15E+06	7.66E+07	1.15E+07	3.44E+07	6.20E+09	2.06E+11	5.89E+16	1.13E+09
17	32.000	8.891	228.490	3.314	2.82E+17	1.18E+12	9.08E+13	2.03E+12	1.97E+10	6.20E+09	2.06E+11	5.89E+16	1.13E+09
						3.38E+06	1.97E+09	2.03E+04	2.82E+08	7.69E+06	9.02E+07	3.38E+08	5.92E+05
						8.46E+05	1.13E+08	1.79E+06	2.82E+07	4.93E+09	1.36E+11	4.30E+16	1.44E+09
18	34.000	6.634	233.743	2.199	2.05E+17	8.94E+11	6.62E+13	1.58E+12	1.03E+10	1.19E+07	6.99E+07	3.29E+08	4.93E+05
						2.26E+06	1.13E+09	2.06E+04	1.23E+08	1.19E+07	6.99E+07	3.29E+08	4.93E+05
						6.17E+05	1.03E+08	1.23E+06	2.26E+07	4.07E+09	8.60E+10	3.15E+16	1.36E+09
19	36.000	4.985	239.282	1.614	1.51E+17	6.64E+11	4.86E+13	1.22E+12	4.83E+09	1.96E+07	5.43E+07	2.72E+08	4.68E+05
						1.66E+06	7.54E+08	1.51E+04	5.28E+07	1.96E+07	5.43E+07	2.72E+08	4.68E+05
						4.53E+05	9.05E+07	3.77E+05	1.81E+07	3.35E+09	5.36E+10	2.33E+16	1.12E+09
20	38.000	3.771	244.818	1.193	1.12E+17	4.91E+11	3.59E+13	8.70E+11	2.45E+09	2.45E+07	4.24E+07	1.90E+08	4.35E+05
						1.34E+06	5.03E+08	1.12E+04	2.23E+07	2.45E+07	4.24E+07	1.90E+08	4.35E+05
						3.35E+05	7.81E+07	1.12E+05	1.34E+07	2.49E+09	3.32E+10	1.74E+16	9.97E+08
21	40.000	2.871	250.350	.888	8.31E+16	3.74E+11	2.61E+13	6.06E+11	1.33E+09	2.57E+07	3.32E+07	1.25E+08	4.24E+05
						1.08E+06	2.91E+08	8.31E+03	8.31E+06	1.80E+09	1.92E+10	1.25E+16	6.60E+08
						2.49E+05	5.98E+07	4.15E+04	9.14E+06	2.40E+07	2.46E+07	3.40E+07	3.84E+05
22	42.000	2.120	255.878	.642	6.00E+16	2.70E+11	1.53E+13	3.84E+11	6.00E+08	1.80E+09	1.92E+10	1.25E+16	6.60E+08
						9.03E+05	1.80E+08	6.00E+03	4.20E+06	2.40E+07	2.46E+07	3.40E+07	3.84E+05
						1.80E+05	3.60E+07	1.20E+04	5.70E+06	1.41E+09	1.17E+10	9.82E+15	4.70E+08
23	44.000	1.695	261.403	.502	4.70E+16	2.11E+11	1.51E+13	2.72E+11	3.29E+08	2.35E+07	1.97E+07	6.11E+07	3.29E+05
						8.45E+05	1.17E+08	4.70E+03	1.88E+06	1.07E+09	7.13E+09	7.45E+15	3.56E+08
						1.41E+05	1.41E+07	3.76E+03	3.76E+06	2.14E+07	1.53E+07	4.63E+07	2.60E+05
24	46.000	1.313	266.925	.381	3.56E+16	1.64E+11	1.15E+13	1.1E+11	1.43E+08	2.14E+07	1.53E+07	4.63E+07	2.60E+05
						8.19E+05	7.13E+07	3.56E+03	7.13E+05	1.80E+09	1.92E+10	1.25E+16	6.60E+08
						1.07E+05	6.06E+06	8.91E+02	2.32E+06	1.41E+09	1.17E+10	9.82E+15	4.70E+08
25	48.000	1.023	270.650	.293	2.74E+16	1.31E+11	8.62E+12	1.04E+11	5.5E+07	8.21E+08	4.11E+09	5.72E+15	2.74E+08
						8.49E+05	4.15E+07	2.74E+03	2.74E+05	1.32E+07	1.20E+07	3.56E+07	2.03E+05
						8.21E+04	3.56E+05	2.74E+02	1.40E+05	1.32E+07	1.20E+07	3.56E+07	2.03E+05
26	50.000	.777	270.650	.228	2.14E+16	1.07E+11	6.88E+12	6.62E+10	2.14E+07	6.41E+08	2.14E+09	4.46E+15	2.14E+08
						7.47E+05	2.14E+07	2.14E+03	1.07E+05	1.71E+07	9.61E+06	2.78E+07	1.58E+05

Table 4b. Sample Input and Output - Case 2 (Contd)

27	55.000	.425	260.771	.126	1.18E+16	5.91E+10	3.80E+12	0.	0.	0.	0.	3.19E+09	2.24E+09	1.77E+10	2.47E+15	0.
28	60.000	.230	247.021	.069	6.44E+15	3.22E+10	2.07E+12	0.	0.	0.	0.	7.45E+09	1.22E+09	9.68E+09	1.35E+15	0.
29	65.000	.109	233.292	.036	3.39E+15	1.70E+10	1.09E+12	0.	0.	0.	0.	9.16E+08	6.45E+08	5.09E+09	7.11E+14	0.
30	70.000	.052	219.585	.018	1.72E+15	8.61E+09	5.54E+11	0.	0.	0.	0.	4.63E+08	3.27E+08	2.58E+09	3.61E+14	0.
31	75.000	.024	208.399	.009	8.31E+14	4.15E+09	2.67E+11	0.	0.	0.	0.	2.24E+08	1.58E+08	1.25E+09	1.74E+14	0.
32	80.000	.011	198.639	.004	3.83E+14	1.91E+09	1.23E+11	0.	0.	0.	0.	1.03E+08	7.27E+07	5.74E+08	8.02E+13	0.
33	85.000	.005	188.893	.002	1.73E+14	8.63E+08	5.56E+10	0.	0.	0.	0.	4.66E+07	3.28E+07	2.59E+08	3.61E+13	0.
34	90.000	.002	186.870	.001	6.98E+13	3.49E+08	2.25E+10	0.	0.	0.	0.	1.88E+07	1.33E+07	1.05E+08	1.46E+13	0.
35	95.000	.001	188.420	.000	3.08E+13	1.54E+08	9.90E+09	0.	0.	0.	0.	8.30E+06	5.84E+06	4.61E+07	5.44E+12	0.
36	100.000	.000	195.080	.000	1.11E+13	5.57E+07	3.59E+09	0.	0.	0.	0.	3.01E+06	2.12E+06	1.67E+07	2.33E+12	0.

CASE 3A: GIVEN H1, H2=SPACE, ANGLE

ISLAND PATH PARAMETERS IN STANDARD FORM

H1	=	33.000	KM
H2	=	100.000	KM
ANGLE	=	94.870	DEG
PHI	=	99.572	DEG
HMIN	=	9.255	KM
LEN	=	1	

ASCODE LAYER BOUNDARIES PRODUCED BY THE AUTOMATIC LAYERING ROUTINE AUTLAY
THE USER SHOULD EXAMINE THESE BOUNDARIES AND MODIFY THEM IF APPROPRIATE
THE FOLLOWING PARAMETERS ARE USED:

AVTRAT	=	2.00	= MAX RATIO OF VOIGT WIDTHS
TDIFF1	=	50.00	= MAX TEMP DIFF AT HMIN
TDIFF2	=	50.00	= MAX TEMP DIFF AT HMAX

Table 4b. Sample Input and Output - Case 2 (Contd)

ALZERO = .100 CM-1 = AVERAGE LORENTZ WIDTH AT STP		AVMWT = 36.00 = AVERAGE MOLECULAR WEIGHT		VBAR = 825.00 CM-1 = AVERAGE WAVENUMBER											
I	Z (KM)	P (MB)	T (K)	LORENTZ (CM-1)	DOPPLER (CM-1)	ZETA	VOIGT (CM-1)	VOIGT RATIO	DBEND (DEG)	BENDING (DEG)	PBAR (MB)	TBAR (K)	RHOBAR (MOL CM-3)		
1	9.255	295.960	228.082	.03327	.00074	.978	.03329	1.97		11.4					
2	13.800	146.221	216.650	.01687	.00072	.959	.01690	1.98		0.0					
3	18.200	73.317	216.650	.00846	.00072	.921	.00852	1.99		2.6					
4	22.700	36.326	219.269	.00417	.00073	.851	.00429	2.00		5.1					
5	27.800	16.658	224.329	.00189	.00074	.719	.00214	2.00		15.5					
6	36.200	4.848	239.836	.00053	.00076	.411	.00107	1.58		50.0					
7	84.500	.005	189.868	.00000	.00068	.001	.00068	.99		5.2					
8	100.000	.000	195.080	.00000	.00069	.000	.00069	0.00		0.0					
1 CALCULATION OF THE REFRACTED PATH THROUGH THE ATMOSPHERE															
I	ALTITUDE FROM (KM)	TO (KM)	THETA (DEG)	D RANGE (KM)	R RANGE (KM)	DBETA (DEG)	BETA (DEG)	PHI (DEG)	DBEND (DEG)	BENDING (DEG)	PBAR (MB)	TBAR (K)	RHOBAR (MOL CM-3)		
1	9.255	10.000	90.000	101.441	101.441	.911	.911	90.843		.068	285.647	226.502	9.13E+18		
2	10.000	12.000	89.157	93.235	194.677	.837	1.748	91.618		.061	233.072	220.435	7.60E+18		
3	12.000	13.800	88.382	55.690	250.367	.500	2.247	92.087		.030	171.107	216.650	5.68E+18		
4	13.800	14.000	87.913	5.431	255.798	.049	2.296	92.134		.003	143.963	216.650	4.81E+18		
5	14.000	16.000	87.866	48.925	304.723	.439	2.735	92.553		.019	123.174	216.650	4.08E+18		
6	16.000	18.000	87.447	41.922	346.644	.376	3.110	92.917		.012	89.890	216.650	2.98E+18		
7	18.000	18.200	87.083	3.908	350.552	.035	3.145	92.951		.001	74.485	216.650	2.49E+18		
8	18.200	20.000	87.049	33.325	383.877	.298	3.443	93.242		.007	64.443	216.650	2.14E+18		
9	20.000	22.000	86.758	33.816	417.693	.303	3.746	93.539		.005	48.001	217.546	1.58E+18		
10	22.000	22.700	86.461	11.183	428.878	.100	3.846	93.638		.001	38.410	218.914	1.27E+18		
11	22.700	24.000	86.352	20.002	448.878	.179	4.025	93.815		.002	33.049	219.887	1.08E+18		
12	24.000	26.000	86.185	29.081	477.959	.260	4.285	94.072		.002	25.847	221.488	8.39E+17		
13	26.000	27.800	85.928	24.684	502.643	.220	4.505	94.291		.001	19.296	223.386	6.23E+17		
14	27.800	29.000	85.709	2.695	505.308	.024	4.529	94.315		.000	16.410	224.427	5.30E+17		
15	28.000	30.000	85.685	25.893	531.201	.231	4.760	94.545		.001	14.086	225.457	4.49E+17		
16	30.000	32.000	85.455	24.646	555.847	.220	4.980	94.764		.001	10.444	227.440	3.30E+17		
17	32.000	33.000	85.236	11.908	567.755	.106	5.086	94.870		.000	8.289	229.762	2.61E+17		
0	DOUBLE RANGE, BETA, BENDING FOR SYMMETRIC PART OF PATH									.432					
H1 TO H2															
18	33.000	34.000	85.130	11.656	1147.166	.104	10.276	94.974		.000	7.160	232.389	2.23E+17		
19	34.000	36.000	85.026	22.613	1169.779	.201	10.478	95.175		.000	5.818	236.342	1.77E+17		
20	36.000	36.200	84.825	2.213	1171.992	.020	10.497	95.194		.000	4.916	239.557	1.49E+17		
21	36.200	38.000	84.806	19.555	1191.548	.174	10.671	95.368		.000	4.314	242.153	1.28E+17		
22	38.000	40.000	84.632	21.013	1212.561	.187	10.858	95.555		.000	3.325	247.423	9.67E+16		
23	40.000	42.000	84.445	20.331	1232.892	.181	11.039	95.736		.000	2.499	252.941	7.10E+16		
24	42.000	44.000	84.264	19.712	1252.604	.175	11.214	95.911		.000	1.909	258.505	5.33E+16		

Table 4b. Sample Input and Output - Case 2 (Contd)

I	LAYER BOUNDARIES		AIR	H2O		CO2		O3		N2O		HNO3		H2CO		CH4		O2		HCL		HBR	
	FROM (KM)	TO (KM)		SO2	HI	NO2	CLO	NO2	NO3	CH	OH	CH	OH	CH	OH	HF	HF	HCL	HCL	HCL	HCL	HBR	HBR
25	44.000	46.000	84.089	19.147	1271.751	.170	11.394	96.081	.000	.000	.000	.000	.000	.000	.000	.000	.000	.434	1.506	264.015	4.11E+16	1.506	264.015
26	46.000	48.000	83.919	18.628	1230.379	.165	11.550	96.246	.000	.000	.000	.000	.000	.000	.000	.000	.000	.434	1.169	268.694	3.13E+16	1.169	268.694
27	48.000	50.000	83.754	18.150	1308.529	.161	11.711	95.407	.000	.000	.000	.000	.000	.000	.000	.000	.000	.434	.911	270.650	2.43E+16	.911	270.650
28	50.000	55.000	83.593	43.504	1352.033	.395	12.096	96.782	.000	.000	.000	.000	.000	.000	.000	.000	.000	.434	.612	266.211	1.62E+16	.612	266.211
29	55.000	60.000	83.208	41.176	1393.209	.384	12.460	97.157	.000	.000	.000	.000	.000	.000	.000	.000	.000	.434	.342	254.583	8.88E+15	.342	254.583
30	60.000	65.000	82.843	39.191	1432.401	.346	12.807	97.503	.000	.000	.000	.000	.000	.000	.000	.000	.000	.434	.164	240.871	4.77E+15	.164	240.871
31	65.000	70.000	82.497	37.472	1469.872	.330	13.137	97.833	.000	.000	.000	.000	.000	.000	.000	.000	.000	.434	.081	227.186	2.47E+15	.081	227.186
32	70.000	75.000	82.167	35.964	1505.836	.317	13.452	98.150	.000	.000	.000	.000	.000	.000	.000	.000	.000	.434	.038	214.652	1.23E+15	.038	214.652
33	75.000	80.000	81.850	34.528	1540.464	.304	13.758	98.454	.000	.000	.000	.000	.000	.000	.000	.000	.000	.434	.017	204.132	5.79E+14	.017	204.132
34	80.000	84.500	81.546	30.140	1570.603	.285	14.023	98.719	.000	.000	.000	.000	.000	.000	.000	.000	.000	.434	.008	194.762	2.74E+14	.008	194.762
35	84.500	85.000	81.281	3.293	1573.896	.029	14.052	98.748	.000	.000	.000	.000	.000	.000	.000	.000	.000	.434	.005	189.386	1.80E+14	.005	189.386
36	85.000	90.000	81.252	32.356	1606.252	.284	14.335	99.031	.000	.000	.000	.000	.000	.000	.000	.000	.000	.434	.003	188.035	1.14E+14	.003	188.035
37	90.000	95.000	80.969	31.379	1637.631	.275	14.610	99.306	.000	.000	.000	.000	.000	.000	.000	.000	.000	.434	.001	187.536	4.77E+13	.001	187.536
38	95.000	100.000	80.694	30.488	1668.119	.266	14.876	99.572	.000	.000	.000	.000	.000	.000	.000	.000	.000	.434	.001	191.163	1.94E+13	.001	191.163
INTEGRATED ABSORBER AMOUNTS BY LAYER																							
INTEGRATED AMOUNTS (MOL CM-2)																							
I																							
1	9.255	10.000	9.258E+25	4.747E+21	2.982E+22	9.949E+18	2.933E+19	9.686E+18	1.482E+20	1.935E+25	2.778E+16	1.482E+20	1.935E+25	2.778E+16	1.482E+20	1.935E+25	2.778E+16	1.482E+20	1.935E+25	2.778E+16	1.482E+20	1.935E+25	2.778E+16
2	10.000	12.000	7.089E+25	9.004E+20	2.283E+22	1.375E+19	2.238E+19	6.462E+18	1.134E+20	1.482E+25	2.127E+16	1.134E+20	1.482E+25	2.127E+16	1.134E+20	1.482E+25	2.127E+16	1.134E+20	1.482E+25	2.127E+16	1.134E+20	1.482E+25	2.127E+16
3	12.000	13.800	3.165E+25	1.434E+20	1.019E+22	1.203E+19	9.680E+18	2.103E+18	4.932E+19	6.614E+24	9.494E+15	4.932E+19	6.614E+24	9.494E+15	4.932E+19	6.614E+24	9.494E+15	4.932E+19	6.614E+24	9.494E+15	4.932E+19	6.614E+24	9.494E+15
4	13.800	14.000	2.614E+24	7.863E+18	8.415E+20	1.276E+18	7.853E+17	1.388E+17	3.933E+18	5.462E+23	7.841E+14	3.933E+18	5.462E+23	7.841E+14	3.933E+18	5.462E+23	7.841E+14	3.933E+18	5.462E+23	7.841E+14	3.933E+18	5.462E+23	7.841E+14
5	14.000	16.000	1.998E+25	6.066E+19	6.435E+21	1.250E+19	5.903E+18	7.987E+17	2.988E+19	4.177E+24	5.715E+15	2.988E+19	4.177E+24	5.715E+15	2.988E+19	4.177E+24	5.715E+15	2.988E+19	4.177E+24	5.715E+15	2.988E+19	4.177E+24	5.715E+15
6	16.000	18.000	1.250E+25	4.113E+19	4.024E+21	1.447E+19	3.507E+18	3.128E+17	1.816E+19	2.612E+24	3.136E+15	1.816E+19	2.612E+24	3.136E+15	1.816E+19	2.612E+24	3.136E+15	1.816E+19	2.612E+24	3.136E+15	1.816E+19	2.612E+24	3.136E+15
7	18.000	18.200	9.730E+23	3.313E+18	3.133E+20	1.595E+18	2.612E+17	1.918E+16	1.357E+18	2.034E+23	2.247E+14	1.357E+18	2.034E+23	2.247E+14	1.357E+18	2.034E+23	2.247E+14	1.357E+18	2.034E+23	2.247E+14	1.357E+18	2.034E+23	2.247E+14
8	18.200	20.000	7.132E+24	4.751E+13	4.053E+14	8.656E+12	1.033E+13	1.289E+11	2.542E+13	3.936E+14	1.554E+12	2.542E+13	3.936E+14	1.554E+12	2.542E+13	3.936E+14	1.554E+12	2.542E+13	3.936E+14	1.554E+12	2.542E+13	3.936E+14	1.554E+12
9	20.000	22.000	5.360E+24	2.462E+19	2.297E+21	1.482E+19	1.812E+18	1.231E+17	9.608E+18	1.491E+24	1.714E+15	9.608E+18	1.491E+24	1.714E+15	9.608E+18	1.491E+24	1.714E+15	9.608E+18	1.491E+24	1.714E+15	9.608E+18	1.491E+24	1.714E+15
10	22.000	22.700	1.420E+24	2.800E+14	4.454E+15	2.536E+13	1.085E+16	1.136E+12	2.890E+14	3.211E+15	1.213E+13	2.890E+14	3.211E+15	1.213E+13	2.890E+14	3.211E+15	1.213E+13	2.890E+14	3.211E+15	1.213E+13	2.890E+14	3.211E+15	1.213E+13
11	22.700	24.000	2.170E+24	2.142E+13	2.890E+13	1.339E+15	2.388E+14	9.286E+16	6.433E+18	1.120E+24	1.401E+15	6.433E+18	1.120E+24	1.401E+15	6.433E+18	1.120E+24	1.401E+15	6.433E+18	1.120E+24	1.401E+15	6.433E+18	1.120E+24	1.401E+15
12	24.000	26.000	2.438E+24	4.969E+18	4.571E+20	5.351E+18	2.734E+17	2.295E+16	1.537E+18	2.967E+23	4.476E+14	1.537E+18	2.967E+23	4.476E+14	1.537E+18	2.967E+23	4.476E+14	1.537E+18	2.967E+23	4.476E+14	1.537E+18	2.967E+23	4.476E+14
				3.046E+13	1.893E+15	1.420E+11	4.476E+15	8.275E+11	1.533E+14	7.926E+14	2.414E+12	1.533E+14	7.926E+14	2.414E+12	1.533E+14	7.926E+14	2.414E+12	1.533E+14	7.926E+14	2.414E+12	1.533E+14	7.926E+14	2.414E+12
				4.259E+12	1.502E+13	2.561E+14	5.901E+13	3.614E+16	2.242E+18	4.535E+23	7.386E+14	2.242E+18	4.535E+23	7.386E+14	2.242E+18	4.535E+23	7.386E+14	2.242E+18	4.535E+23	7.386E+14	2.242E+18	4.535E+23	7.386E+14
				7.595E+18	6.987E+20	9.330E+18	3.748E+17	1.752E+12	2.846E+14	1.264E+15	3.689E+12	2.846E+14	1.264E+15	3.689E+12	2.846E+14	1.264E+15	3.689E+12	2.846E+14	1.264E+15	3.689E+12	2.846E+14	1.264E+15	3.689E+12
				4.334E+13	3.913E+15	2.170E+11	7.886E+15	1.752E+12	2.846E+14	1.264E+15	3.689E+12	2.846E+14	1.264E+15	3.689E+12	2.846E+14	1.264E+15	3.689E+12	2.846E+14	1.264E+15	3.689E+12	2.846E+14	1.264E+15	3.689E+12
				6.510E+12	3.461E+13	3.744E+14	1.007E+14	3.545E+17	4.258E+16	2.357E+18	5.096E+23	4.258E+16	2.357E+18	5.096E+23	4.258E+16	2.357E+18	5.096E+23	4.258E+16	2.357E+18	5.096E+23	4.258E+16	2.357E+18	5.096E+23

Table 4b. Sample Input and Output - Case 2 (Contd)

13	25,000	27,800	1.535E+24	4.400E+13	6.331E+15	2.35E+11	9.189E+15	4.209E+12	4.200E+14	1.519E+15	4.145E+12
				7.315E+12	7.758E+13	3.056E+14	1.330E+14				
				5.607E+18	4.941E+20	9.067E+18	1.806E+17	2.527E+16	1.381E+18	3.207E+23	1.525E+15
				2.475E+13	5.600E+15	1.555E+11	5.034E+15	6.220E+12	3.380E+14	1.030E+15	2.509E+12
14	27,800	28,000	1.411E+23	4.604E+12	1.047E+14	1.402E+14	1.043E+14	2.675E+15	1.219E+17	2.950E+22	2.052E+14
				5.490E+17	4.545E+19	6.714E+17	1.566E+16	8.295E+11	3.489E+13	9.844E+13	2.400E+11
				2.131E+12	6.234E+14	1.411E+10	4.267E+14	1.702E+16	6.236E+17	1.700E+23	2.561E+15
				4.234E+11	1.363E+13	1.011E+13	1.113E+13	2.263E+16	9.667E+17	2.430E+23	2.242E+15
15	28,000	30,000	1.163E+24	4.643E+18	3.744E+20	7.425E+18	1.666E+17	9.040E+12	3.171E+14	9.676E+14	2.031E+12
				1.632E+13	6.725E+15	1.163E+11	2.902E+15	1.040E+12	3.171E+14	9.676E+14	2.031E+12
				3.486E+12	1.543E+14	5.67E+13	9.837E+13	1.381E+13	2.516E+14	8.877E+14	1.576E+12
16	30,000	32,000	8.136E+23	3.374E+18	2.620E+20	5.536E+18	6.522E+16	1.702E+16	6.236E+17	1.700E+23	2.561E+15
				1.019E+13	5.908E+15	8.136E+10	1.197E+15	1.381E+13	2.516E+14	8.877E+14	1.576E+12
				2.441E+12	2.301E+14	1.833E+13	7.696E+13	6.979E+15	2.213E+17	6.491E+22	1.428E+15
17	32,000	33,000	3.105E+23	1.312E+18	1.000E+20	2.273E+18	2.006E+16	1.043E+13	1.009E+14	4.000E+14	6.738E+11
				3.649E+12	2.052E+15	3.166E+10	2.751E+14	1.043E+13	1.009E+14	4.000E+14	6.738E+11
				9.317E+11	1.312E+14	4.147E+12	3.179E+13	6.093E+15	1.759E+17	5.425E+22	1.579E+15
18	33,000	34,000	2.596E+23	1.110E+18	8.359E+19	1.965E+18	1.417E+16	6.093E+15	1.759E+17	5.425E+22	1.579E+15
				2.920E+12	1.520E+15	2.596E+10	1.781E+14	1.255E+13	8.690E+13	3.860E+14	6.321E+11
				7.789E+11	1.226E+14	2.059E+12	2.787E+13	1.016E+16	2.467E+17	8.365E+22	3.162E+15
19	34,000	36,000	4.002E+23	1.740E+18	1.289E+20	3.157E+18	1.635E+16	3.489E+15	1.398E+14	6.773E+14	1.087E+12
				4.403E+12	2.105E+15	4.002E+10	1.885E+14	1.016E+16	2.467E+17	8.365E+22	3.162E+15
				1.201E+12	2.184E+14	1.640E+12	4.588E+13	8.929E+14	1.859E+16	6.876E+21	2.976E+14
20	36,000	36,200	3.290E+22	1.447E+17	1.059E+19	2.650E+17	1.033E+15	4.391E+12	1.187E+13	5.905E+13	1.032E+11
				3.634E+11	1.636E+14	3.230E+09	1.120E+13	7.163E+15	1.307E+17	5.243E+22	2.388E+15
				9.869E+10	1.989E+13	7.861E+10	3.948E+12	4.344E+13	9.293E+13	4.382E+14	8.793E+11
21	36,200	38,000	2.509E+23	1.104E+18	8.078E+19	1.932E+18	6.196E+16	6.095E+15	8.959E+16	4.246E+22	2.218E+15
				2.890E+12	1.87E+15	2.509E+10	6.605E+13	5.282E+13	7.911E+13	3.258E+14	9.322E+11
				7.526E+11	1.634E+14	3.978E+11	3.010E+13	3.055E+13	5.839E+13	2.096E+14	8.206E+11
22	38,000	40,000	2.032E+23	9.035E+17	6.542E+19	1.536E+18	3.861E+15	6.095E+15	8.959E+16	4.246E+22	2.218E+15
				2.533E+12	8.140E+14	2.032E+10	2.986E+13	4.329E+15	5.207E+16	3.016E+22	1.563E+15
				5.095E+11	1.441E+14	1.493E+11	2.541E+13	5.055E+13	5.839E+13	2.096E+14	8.206E+11
23	40,000	42,000	1.443E+23	6.493E+17	4.506E+19	9.908E+17	1.868E+15	3.149E+15	2.993E+16	2.194E+22	1.104E+15
				2.008E+12	4.705E+14	1.433E+10	1.236E+13	4.680E+13	4.354E+13	1.419E+14	7.014E+11
				4.329E+11	9.548E+13	4.651E+10	1.403E+13	2.359E+15	1.772E+16	1.643E+22	7.362E+14
24	42,000	44,000	1.050E+23	4.724E+17	3.380E+19	6.412E+17	8.901E+14	3.149E+15	2.993E+16	2.194E+22	1.104E+15
				1.720E+12	2.831E+14	1.050E+10	5.699E+12	4.293E+13	3.339E+13	1.022E+14	5.314E+11
				3.149E+11	4.614E+13	1.403E+10	9.198E+12	1.751E+15	1.022E+16	1.220E+22	5.338E+14
25	44,000	46,000	7.862E+22	3.575E+17	2.532E+19	4.134E+17	4.274E+14	3.773E+13	2.538E+13	7.589E+13	4.289E+11
				1.504E+12	1.772E+14	7.662E+09	2.309E+12	1.321E+15	5.478E+15	9.200E+21	4.402E+14
				2.359E+11	1.825E+13	3.825E+09	5.709E+12	3.287E+13	1.958E+13	5.722E+13	3.257E+11
26	46,000	48,000	5.838E+22	2.741E+17	1.890E+19	2.464E+17	1.712E+14	1.751E+15	1.022E+16	1.220E+22	5.338E+14
				1.553E+12	1.032E+14	5.838E+09	8.562E+11	1.321E+15	5.478E+15	9.200E+21	4.402E+14
				1.751E+11	8.761E+12	9.765E+08	3.389E+12	3.287E+13	1.958E+13	5.722E+13	3.257E+11
27	48,000	50,000	4.402E+22	2.155E+17	1.417E+19	1.500E+17	6.450E+13	1.321E+15	5.478E+15	9.200E+21	4.402E+14
				1.447E+12	5.478E+13	4.402E+09	2.235E+11	5.335E+13	3.174E+16	1.471E+22	4.890E+14
				1.371E+11	5.063E+12	4.402E+08	2.044E+12	3.752E+13	2.110E+13	6.097E+13	3.470E+11
28	50,000	55,000	7.031E+22	3.515E+17	2.264E+19	1.454E+17	2.705E+15	3.752E+13	2.110E+13	6.097E+13	3.470E+11
				1.611E+12	4.650E+13	4.690E+09	2.345E+11	6.946E+15	5.484E+16	7.658E+21	0.
				1.407E+11	4.690E+12	4.690E+08	1.876E+12	0.	0.	0.	0.
29	55,000	60,000	3.656E+22	1.828E+17	1.177E+19	0.	0.	0.	0.	0.	0.
				0.	0.	0.	0.	0.	0.	0.	0.
				0.	0.	0.	0.	0.	0.	0.	0.
30	60,000	65,000	1.868E+22	9.340E+16	6.015E+18	0.	0.	0.	0.	0.	0.
				0.	0.	0.	0.	0.	0.	0.	0.
				0.	0.	0.	0.	0.	0.	0.	0.

Table 4b. Sample Input and Output - Case 2 (Contd)

31	65.000	70.000	9.254E+21	4.627E+16	2.980E+18	0.	0.	0.	2.499E+15	1.758E+15	1.388E+16	1.939E+21	0.
						0.	0.	0.	0.	0.	0.	0.	0.
32	70.000	75.000	4.407E+21	2.204E+16	1.419E+18	0.	0.	0.	1.190E+15	8.373E+14	6.611E+15	9.232E+20	0.
						0.	0.	0.	0.	0.	0.	0.	0.
33	75.000	80.000	2.007E+21	1.003E+16	6.461E+17	0.	0.	0.	5.418E+14	3.812E+14	3.010E+15	4.203E+20	0.
						0.	0.	0.	0.	0.	0.	0.	0.
34	80.000	84.500	8.250E+20	4.125E+15	2.656E+17	0.	0.	0.	2.227E+14	1.567E+14	1.237E+15	1.728E+20	0.
						0.	0.	0.	0.	0.	0.	0.	0.
35	84.500	85.000	5.914E+19	2.957E+14	1.904E+16	0.	0.	0.	1.597E+13	1.124E+13	8.872E+13	1.239E+19	0.
						0.	0.	0.	0.	0.	0.	0.	0.
36	85.000	90.000	3.681E+20	1.841E+15	1.185E+17	0.	0.	0.	9.939E+13	6.994E+13	5.522E+14	7.711E+19	0.
						0.	0.	0.	0.	0.	0.	0.	0.
37	90.000	95.000	1.497E+20	7.487E+14	4.821E+16	0.	0.	0.	4.043E+13	2.845E+13	2.246E+14	3.137E+19	0.
						0.	0.	0.	0.	0.	0.	0.	0.
38	95.000	100.000	5.901E+19	2.951E+14	1.900E+16	0.	0.	0.	1.593E+13	1.121E+13	8.852E+13	1.236E+19	0.
						0.	0.	0.	0.	0.	0.	0.	0.
OTOTAL	33.000	100.000	5.090E+26	1.198E+22	1.639E+23	3.106E+20	1.532E+20	3.988E+19	7.806E+20	1.064E+26	1.792E+17	1.792E+17	1.792E+17
						2.856E+16	2.362E+17	2.096E+17	1.767E+17	5.206E+14	6.968E+15	4.917E+16	8.701E+14
						1.527E+15	2.728E+15	2.377E+17	1.875E+16				

1 SUMMARY OF THE GEOMETRY CALCULATION

MODEL	=	US 76 + TRACE GASES
H1	=	33.000 KM
H2	=	100.000 KM
ANGLE	=	94.870 DEG
RANGE	=	1668.119 KM
BETA	=	14.876 DEG
PHI	=	99.572 DEG
HMIN	=	9.255 KM
BENDING	=	.434 DEG
LEN	=	1

AIRMAS = 23.6 RELATIVE TO A VERTICAL PATH, GROUND TO SPACE

OFFINAL SET OF LAYERS FOR INPUT TO FASCODI
A LAYER AMOUNT MAY BE SET TO ZERO IF THE CUMULATIVE AMOUNT FOR THAT LAYER AND ABOVE IS LESS THAN 0.1 PERCENT OF THE TOTAL AMOUNT. THIS IS DONE ONLY FOR THE FOLLOWING CASES

1. IEMIT = 0 (TRANSMITTANCE)
2. IEMIT = 1 (RADIANCE) AND ICNTRL = 3 (PATH LOOKING UP)

Q2 IS NOT INCLUDED
IF THE AMOUNTS FOR ALL THE MOLECULES BUT Q2 ARE ZEROED, THE REMAINING LAYERS ARE ELIMINATED

L	LAYER BOUNDARIES FROM (KM)	ICNTRL TO (KM)	PBAR (MB)	TBAR (K)	AIR	H2O S02 HI	CO2 NO2 CLO	O3 NH3 OCS	N2O HNO3 H2CO	CH4 HF	O2 HCL	NO HBR
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Table 4b. Sample Input and Output - Case 2 (Contd)

1	9.255	13.800	2	247.97	222.70	1.95E+26	5.79E+21	6.28E+22	3.57E+19	6.17E+19	1.83E+19	3.11E+20	4.08E+20	5.85E+16
							1.16E+16	5.89E+16	9.96E+16	1.90E+16	9.27E+12	2.09E+14	4.68E+15	3.32E+14
							5.85E+14	5.27E+13	1.00E+17	6.95E+15				
2	13.800	18.200	2	111.83	216.65	3.61E+25	1.13E+20	1.16E+22	3.02E+19	1.05E+19	1.26E+18	5.34E+13	7.54E+24	9.86E+15
							2.04E+15	1.27E+16	5.13E+15	1.38E+16	2.84E+12	3.68E+14	5.67E+15	6.13E+13
							1.08E+14	4.56E+13	1.46E+16	1.30E+15				
3	18.200	22.700	2	55.45	217.23	1.39E+25	4.83E+19	4.48E+21	3.65E+19	3.27E+18	2.29E+17	1.76E+19	2.91E+24	3.62E+15
							4.53E+14	1.19E+16	0.	2.84E+16	3.66E+12	8.54E+14	6.81E+15	2.37E+13
							4.17E+13	8.62E+13	3.35E+15	4.92E+14				
4	22.700	27.800	2	26.75	221.40	6.14E+24	2.22E+19	1.98E+21	3.10E+19	9.15E+17	1.07E+17	5.98E+19	1.28E+24	3.79E+15
							1.13E+14	1.58E+16	0.	2.21E+16	1.22E+13	1.04E+15	3.81E+15	1.04E+13
							1.84E+13	2.17E+14	7.83E+14	3.38E+14				
5	27.800	33.000	2	12.26	226.61	2.43E+24	9.88E+18	7.82E+20	1.62E+19	2.18E+17	4.93E+16	1.93E+18	5.07E+23	6.44E+15
							3.23E+13	1.53E+16	0.	4.80E+15	3.41E+13	7.05E+14	2.35E+15	4.52E+12
							7.28E+12	5.39E+14	0.	2.18E+14				
6	33.000	36.200	3	6.28	235.01	6.93E+23	0.	2.23E+20	5.39E+18	0.	1.71E+16	4.41E+17	1.45E+23	5.04E+15
							0.	3.79E+15	0.	3.78E+14	5.18E+13	2.39E+14	1.12E+15	1.79E+12
							2.08E+12	3.61E+14	0.	7.77E+13				
7	36.200	84.500	3	2.54	252.50	1.03E+24	0.	3.30E+20	6.12E+18	0.	4.53E+16	0.	2.15E+23	9.65E+15
							0.	3.14E+15	0.	0.	3.45E+14	3.79E+14	1.41E+15	4.97E+12
							2.79E+12	4.86E+14	0.	9.05E+13				

Table 4c. Sample Input and Output - Case 3

```
*****INPUT CASE 3*****
 6  2  25  1  1
100.0      0.0      180.0
690.0      700.0
 2.0      4.0      6.0      8.0      10.0      12.0      14.0      16.0
18.0      20.0      22.0      24.0      26.0      28.0      30.0      32.0
34.0      36.0      38.0      40.0      42.0      44.0      46.0      48.0
50.0

*****OUTPUT CASE 3*****
1 *****PROGRAM FSCATM***** 01/11/83 11.03.55.

CONTROL CARD 1: MODEL AND OPTIONS
MODEL = 16
ITYPE = 2
ISND = 25
NOZERO = 1
NOPRNT = 1
KMAX = 0
IPUNCH = 0
RE = 0.000 KM

CONTROL CARD 1 PARAMETERS WITH DEFAULTS:
MODEL = 6
ITYPE = 2
ISND = 25
NOZERO = 1
NOPRNT = 1
KMAX = 7
IPUNCH = 0
RE = 6371.230 KM

SLANT PATH SELECTED. ITYPE = 2

CONTROL CARD 2: SLANT PATH PARAMETERS
H1 = 100.0000 KM
H2 = 0.0000 KM
ANGLE = 180.0000 DEG
RANGE = 0.0000 KM
```

Table 4c. Sample Input and Output - Case 3 (Contd)

BETA	=	0.0000 DEG
LEN	=	0
CONTROL CARD 3		
V1	=	690.000 CM-1
V2	=	700.000 CM-1
VBAR	=	695.000 CM-1
USER DEFINED BOUNDARIES FOR FASCOD1 LAYERS		
I	Z (KM)	
1	2.0000	
2	4.0000	
3	6.0000	
4	8.0000	
5	10.0000	
6	12.0000	
7	14.0000	
8	16.0000	
9	18.0000	
10	20.0000	
11	22.0000	
12	24.0000	
13	26.0000	
14	28.0000	
15	30.0000	
16	32.0000	
17	34.0000	
18	36.0000	
19	38.0000	
20	40.0000	
21	42.0000	
22	44.0000	
23	46.0000	
24	48.0000	
25	50.0000	
1 ATMOSPHERIC PROFILE SELECTED IS: M = 6 U. S. STANDARD, 1962		
CASE 2A: GIVEN H1, H2, ANGLE		
EITHER A SHORT PATH (LEN=0) OR A LONG PATH THROUGH A TANGENT HEIGHT (LEN=1) IS POSSIBLE: LEN = 0		
SLANT PATH PARAMETERS IN STANDARD FORM		
H1	=	100.000 KM
H2	=	0.000 KM

Table 4c. Sample Input and Output - Case 3 (Contd)

ANGLE	=	180.000 DEG
PHI	=	-0.000 DEG
HMIN	=	0.000 KM
LEN	=	0

HALFWIDTH INFORMATION ON THE USER SUPPLIED FASCODI SOUNDCARIES	
THE FOLLOWING VALUES ARE ASSUMED:	
ALZERO	= .100 CM ⁻¹ = AVERAGE LORENTZ WIDTH AT STP
AVNWT	= 36.00 CM ⁻¹ = AVERAGE MOLECULAR WEIGHT
VBAR	= 695.00 CM ⁻¹ = AVERAGE WAVENUMBER

I	Z (KM)	P (MB)	T (K)	LORENTZ (CM ⁻¹)	DOPPLER (CM ⁻¹)	ZETA	VOIGT (CM ⁻¹)	VOIGT RATIO	TEMP DIFF (K)
1	2.000	795.000	275.100	.08139	.00069	.992	.08139	1.26	12.9
2	4.000	616.600	262.200	.06466	.00067	.990	.06466	1.27	13.0
3	6.000	472.200	245.200	.05079	.00065	.987	.05080	1.29	13.0
4	8.000	356.500	236.200	.03939	.00064	.984	.03940	1.31	13.0
5	10.000	265.000	223.200	.03012	.00062	.980	.03013	1.35	6.6
6	12.000	194.000	216.600	.02232	.00061	.973	.02240	1.37	0.0
7	14.000	141.700	216.600	.01635	.00061	.964	.01637	1.37	0.0
8	16.000	103.500	216.600	.01194	.00061	.951	.01197	1.37	0.0
9	18.000	75.650	216.600	.00873	.00061	.935	.00877	1.36	0.0
10	20.000	55.290	216.600	.00638	.00061	.913	.00644	1.36	2.0
11	22.000	40.470	216.600	.00465	.00061	.883	.00473	1.35	2.0
12	24.000	29.720	220.600	.00340	.00062	.846	.00351	1.33	2.0
13	26.000	21.914	222.580	.00249	.00062	.801	.00264	1.30	2.0
14	28.000	16.196	224.540	.00184	.00062	.747	.00203	1.27	2.0
15	30.000	11.970	226.500	.00135	.00062	.684	.00159	1.22	2.0
16	32.000	8.925	230.500	.00100	.00063	.613	.00130	1.18	4.0
17	34.000	6.654	234.500	.00074	.00064	.537	.00110	1.13	5.4
18	36.000	5.001	239.880	.00055	.00064	.460	.00097	1.10	6.8
19	38.000	3.789	246.640	.00041	.00065	.386	.00089	1.07	6.8
20	40.000	2.871	253.400	.00031	.00066	.317	.00083	1.05	4.3
21	42.000	2.209	257.720	.00023	.00067	.260	.00079	1.03	4.3
22	44.000	1.700	262.040	.00018	.00067	.210	.00077	1.02	3.4
23	46.000	1.316	265.420	.00014	.00068	.169	.00075	1.02	2.6
24	48.000	1.025	268.040	.00011	.00068	.135	.00073	1.01	2.6
25	50.000	.798	270.600	.00009	.00068	.108	.00072	0.00	0.0

1 SUMMARY OF THE GEOMETRY CALCULATION

MODEL	=	U. S. STANDARD, 1962
H1	=	100.000 KM
H2	=	0.000 KM
ANGLE	=	180.000 DEG
RANGE	=	100.000 KM
BETA	=	.000 DEG
PHI	=	-0.000 DEG
HMIN	=	0.000 KM
BENDING	=	-0.000 DEG
LEN	=	0
AIRMAS	=	1.00 RELATIVE TO A VERTICAL PATH, GROUND TO SPACE

Table 4c. Sample Input and Output - Case 3 (Contd)

FINAL SET OF LAYERS FOR INPUT TO FASCOD.
A LAYER AMOUNT MAY BE SET TO ZERO IF THE CUMULATIVE AMOUNT FOR THAT LAYER AND ABOVE IS LESS THAN 0.1 PERCENT OF THE TOTAL AMOUNT. THIS IS DONE ONLY FOR THE FOLLOWING CASES

1. IENIT = 0 (TRANSMITTANCE)
2. IENIT = 1 (RADIANCE) AND IENITL = 3 (PATH LOOKING UP)

O2 IS NOT INCLUDED

IF THE AMOUNTS FOR ALL THE MOLECULES BUT O2 ARE ZEROED, THE REMAINING LAYERS ARE ELIMINATED

L	LAYER BOUNDARIES		ICNTRL	PBAR (MB)	IBAR (K)	INTEGRATED AMOUNTS (MOLS CM-2)							
	FROM (KM)	TO (KM)				AIR	H2O	CO2	O3	N2O	CO	CH4	O2
1	0.000	2.000	1	903.76	281.80	4.63E+24	2.85E+22	1.52E+21	1.36E+17	1.29E+18	3.45E+17	7.36E+13	9.64E+23
2	2.000	4.000	1	705.62	268.88	3.78E+24	1.25E+22	1.25E+21	1.25E+17	1.06E+18	2.83E+17	6.04E+13	7.91E+23
3	4.000	6.000	1	544.24	255.92	3.07E+24	4.51E+21	1.01E+21	1.15E+17	8.57E+17	2.30E+17	4.90E+13	6.42E+23
4	6.000	8.000	1	414.24	242.93	2.46E+24	1.50E+21	8.11E+20	1.22E+17	6.88E+17	1.84E+17	3.93E+13	5.15E+23
5	8.000	10.000	1	310.64	229.94	1.95E+24	3.58E+20	6.42E+20	1.77E+17	5.45E+17	1.46E+17	3.11E+13	4.08E+23
6	10.000	12.000	1	229.45	218.49	1.51E+24	6.06E+19	4.98E+20	3.18E+17	4.23E+17	1.13E+17	2.42E+13	3.16E+23
7	12.000	14.000	1	167.85	216.60	1.11E+24	1.30E+19	3.67E+20	4.33E+17	3.12E+17	8.35E+16	1.78E+13	2.33E+23
8	14.000	16.000	1	122.60	216.60	8.13E+23	4.62E+18	2.68E+20	5.33E+17	2.28E+17	6.10E+16	1.30E+13	1.70E+23
9	16.000	18.000	1	89.58	216.60	5.94E+23	3.49E+18	1.96E+20	7.02E+17	1.66E+17	4.46E+16	9.51E+17	1.25E+23
10	18.000	20.000	1	65.47	216.60	4.34E+23	2.94E+18	1.43E+20	8.78E+17	1.22E+17	3.26E+16	6.95E+17	9.10E+22
11	20.000	22.000	1	47.88	217.55	3.16E+23	3.21E+18	1.04E+20	9.60E+17	8.86E+16	2.37E+16	5.06E+17	6.63E+22
12	22.000	24.000	1	35.10	219.55	2.30E+23	3.79E+18	7.58E+19	9.47E+17	6.43E+16	1.72E+16	3.68E+17	4.81E+22
13	24.000	26.000	1	25.81	221.54	1.67E+23	4.21E+18	5.53E+19	8.44E+17	4.69E+16	1.26E+16	2.68E+17	3.51E+22
14	26.000	28.000	1	19.06	223.51	1.23E+23	3.55E+18	4.05E+19	6.91E+17	3.43E+16	9.20E+15	1.96E+17	2.57E+22
15	28.000	30.000	1	14.09	225.47	8.98E+22	2.02E+18	2.97E+19	5.59E+17	2.51E+16	6.74E+15	1.44E+17	1.83E+22
16	30.000	32.000	1	10.45	228.39	6.50E+22	2.15E+18	2.17E+19	4.45E+17	1.84E+16	4.94E+15	1.05E+17	1.38E+22
17	32.000	34.000	1	7.79	232.39	4.82E+22	1.52E+18	1.59E+19	3.51E+17	1.35E+16	3.62E+15	7.72E+15	1.01E+22
18	34.000	36.000	1	5.82	236.71	3.54E+22	1.08E+18	1.17E+19	2.74E+17	9.90E+15	2.65E+15	5.66E+15	7.41E+21
19	36.000	38.000	1	4.40	243.00	.60E+22	7.59E+17	8.60E+18	2.01E+17	7.29E+15	1.95E+15	4.17E+15	5.46E+21
20	38.000	40.000	1	3.33	249.83	1.92E+22	5.36E+17	6.34E+18	1.45E+17	5.37E+15	1.44E+15	3.07E+15	4.02E+21
21	40.000	42.000	1	2.54	255.45	1.43E+22	3.80E+17	4.73E+18	1.00E+17	4.01E+15	1.07E+15	2.29E+15	3.00E+21

Table 4c. Sample Input and Output - Case 3 (Contd)

22	42.000	44.000	1	1.96	259.77	1.08E+22	2.95E+17	3.58E+18	6.56E+16	3.04E+15	8.13E+14	1.73E+15	2.27E+21
23	44.000	46.000	1	1.51	263.90	8.22E+21	2.12E+17	2.71E+18	4.23E+16	2.30E+15	6.17E+14	1.32E+15	1.72E+21
24	46.000	48.000	1	1.17	266.70	6.32E+21	1.45E+17	2.09E+18	2.43E+16	1.77E+15	4.74E+14	1.01E+15	1.33E+21
25	48.000	50.000	1	.91	269.26	4.88E+21	9.83E+16	1.61E+18	1.36E+16	1.37E+15	3.66E+14	7.81E+15	1.02E+21
26	50.000	100.000	1	.39	251.62	1.69E+22	1.84E+17	5.58E+18	2.60E+16	4.74E+15	1.27E+15	2.71E+16	3.55E+21

Table 4d. Sample Input and Output - Case 4

```
*****INPUT CASE 4*****
2 2
8.0 10.0 450.0
800.0 1200.0
1.6 10.0 15.0

*****OUTPUT CASE 4*****
1 *****PROGRAM FSC: TM*****
01/11/83 11.04.18.

CONTROL CARD 1: MODEL AND OPTIONS
MODEL = 2
ITYPE = 2
ISND = 0
NOZERO = 0
NOPRINT = 1
KMAX = 0
IPUNCH = 1
RE = 0.000 KM

CONTROL CARD 1 PARAMETERS WITH DEFAULTS:
MODEL = 2
ITYPE = 2
ISND = 0
NOZERO = 0
NOPRINT = 1
KMAX = 7
IPUNCH = 1
RE = 6371.230 KM

SLANT PATH SELECTED, ITYPE = 2

CONTROL CARD 2: SLANT PATH PARAMETERS
H1 = 8.0000 KM
H2 = 10.0000 KM
ANGLE = 0.0000 DEG
RANGE = 450.0000 KM
BETA = 0.0000 DEG
LEN = 0
```

Table 4d. Sample Input and Output - Case 4 (Contd.)

CONTROL CARD 3

V1 = 800.000 CM-1
V2 = 1200.000 CM-1
VBAR = 1000.000 CM-1

AUTOLAYERING SELECTED

AVTRAT = 1.60
TDIFF1 = 10.00
TDIFF2 = 15.00

1 ATMOSPHERIC PROFILE SELECTED IS: M = 2 MIDLATITUDE SUMMER

CASE 2C: GIVEN H1, H2, RANGE

NOTE: ANGLE 1° COMPUTED FROM H1, H2, AND RANGE ASSUMING NO REFRACTION

SLANT PATH PARAMETERS IN STANDARD FORM

H1 = 8.000 KM
H2 = 10.000 KM
ANGLE = 91.786 DEG
PHI = 92.241 DEG
HMIN = 4.647 KM
LEN = 1

FASCODE LAYER BOUNDARIES PRODUCED BY THE AUTOMATIC LAYERING ROUTINE AUTLAY
THE USER SHOULD EXAMINE THESE BOUNDARIES AND MODIFY THEM IF APPROPRIATE
THE FOLLOWING PARAMETERS ARE USED:

AVTRAT = 1.60 = MAX RATIO OF VOIGT WIDTHS
TDIFF1 = 10.00 = MAX TEMP DIFF AT HMIN
TDIFF2 = 15.00 = MAX TEMP DIFF AT HMAX
ALZERO = .100 CM-1 = AVERAGE LORENTZ WIDTH AT STP
AVMWT = 36.00 = AVERAGE MOLECULAR WEIGHT
VBAR = 1000.00 CM-1 = AVERAGE WAVELENGTH

I	Z (KM)	P (MB)	T (K)	LORENTZ (CM-1)	DOPPLER (CM-1)	ZETA	VOIGT (CM-1)	VOIGT RATIO	TEMP DIFF (K)
1	4.647	579.076	269.119	.05994	.00998	.984	.05995	1.21	9.9
2	6.300	467.835	259.200	.04934	.00996	.981	.04936	1.23	11.2
3	8.000	372.000	248.000	.04011	.00994	.977	.04013	1.27	12.3
4	9.900	285.030	235.700	.03152	.00992	.972	.03155	1.01	.7
5	10.000	281.000	235.000	.03112	.00991	.971	.03115	0.00	0.0

Table 4d. Sample Input and Output - Case 4 (Contd)

1 SUMMARY OF THE GEOMETRY CALCULATION

MODEL	=	MIDLATITUDE SUMMER
H1	=	8.000 KM
H2	=	10.000 KM
ANGLE	=	91.766 DEG
RANGE	=	494.451 KM
BETA	=	4.441 DEG
PHI	=	92.241 DEG
HMIN	=	4.647 KM
BENDING	=	.434 DEG
LEN	=	1
AIRMAS	=	30.9

RELATIVE TO A VERTICAL PATH , GROUND TO SPACE

FINAL SET OF LAYERS FOR INPUT TO FASCOO1

A LAYER AMOUNT MAY BE SET TO ZERO IF THE CUMULATIVE AMOUNT FOR THAT LAYER AND ABOVE IS LESS THAN 0.1 PERCENT OF THE TOTAL AMOUNT. THIS IS DONE ONLY FOR THE FOLLOWING CASES

1. IEMIT = 0 (TRANSMITTANCE)

2. IEMIT = 1 (RADIANCE), AND ICNTRL = 3 (PATH LOOKING UP)

Q2 IS NOT INCLUDED

IF THE AMOUNTS FOR ALL THE MOLECULES BUT O2 ARE ZEROED, THE REMAINING LAYERS ARE ELIMINATED

L	LAYER	BOUNDARIES	ICNTRL	PBAR	TBAR	INTEGRATED AMOUNTS (MOLS CM-2)							
		FROM	TO		(K)	AIR	H2O	CO2	O3	N2O	CO	CH4	O2
		(KM)	(KM)	(MB)									
1	4.647	6.300	2	542.59	265.96	2.26E+26	4.89E+23	7.46E+22	1.29E+19	6.33E+19	1.69E+19	3.62E+20	4.73E+25
2	6.300	8.000	2	422.54	254.30	7.79E+25	7.77E+22	2.57E+22	6.12E+18	2.18E+19	5.84E+18	1.25E+20	1.63E+25
3	8.000	9.900	3	330.11	242.52	5.36E+25	2.39E+22	1.77E+22	5.81E+18	1.50E+19	4.02E+18	8.58E+19	1.12E+25
4	9.900	10.000	3	283.01	235.35	2.24E+24	0.	7.39E+20	2.89E+17	6.27E+17	1.68E+17	3.58E+18	4.69E+23

*****TAPE7 CASE4*****

4 MIDLATITUDE SUMMER													
		H1=	8.00	H2=	10.00	ANGLE=	91.766	LEN=	1				
5.426E+02	265.96	2	6.30E+19	1.69E+19	3.62E+20	4.65	TO	6.30	KM				
4.89E+23	7.46E+22	2	6.30E+19	1.69E+19	3.62E+20	4.73E+25							
4.225E+02	254.30	2	6.30	TO	8.00	KM							
7.77E+22	2.57E+22	2	6.12E+18	2.18E+19	1.25E+20	1.63E+25							
3.301E+02	242.52	3	8.00	TO	9.90	KM							
2.39E+22	1.77E+22	3	5.81E+18	1.50E+19	4.02E+18	8.58E+19							
2.830E+02	235.35	3	6.27E+17	1.68E+17	3.58E+18	4.69E+23							
0.	7.39E+20	2.89E+17	6.27E+17	1.68E+17	3.58E+18	4.69E+23							

The following two pages trace the refracted path through the atmosphere, starting from the lowest point along the path. The layer boundaries for this calculation are the result of merging the atmospheric profile boundaries with the output layer boundaries, from HMIN to HMAX. The column labeled THETA shows the path zenith angle at the bottom of that layer, while DRANGE is the curved path length through the layer. DBETA is the earth-centered angle subtended by that layer. PHI is the arrival angle at the top of the layer, while DBEND is the refractive bending in the layer. PBAR and TBAR are the density-weighted pressure and temperatures for the layer, while RHOBAR is the average density. The next table lists the amounts for each gas for each layer, plus the total for the path.

The last page prints a summary of the path calculation then the amounts for the output layers. Note that the amounts for H_2O are zeroed out above 32.3 km because less than 0.1 percent of the total H_2O amount for this path lies above 32.3 km. The amounts for all the other molecules except O_3 are zeroed out above 49.0 km for the same reason. Finally, the layers above 78.1 km are eliminated entirely since 99.9 percent of the amounts for all the molecules lie below this altitude. This zeroing option can reduce the computation time for a line-by-line calculation. The option can be suppressed by specifying NOZERO = 1 on Card 1.

Case 2, shown in Table 4b, models the conditions of a stratospheric balloon-borne experiment looking at the sun as it sets.¹¹ On Card 1, MODEL = 7 selects a user-supplied atmospheric profile, ITYPE = 3 selects a slant path to space, and KMAX = 20 selects 20 molecular species, the maximum allowed. On Card 2, H1 = 33 km is the altitude of the balloon and ANGLE = 94.88 deg is the apparent or measured zenith angle of the sun. The reported zenith angle of 95.3 deg is the astronomical zenith angle for a straight line to the sun. The apparent zenith angle was found by iteration of the program until the apparent zenith angle (ANGLE) plus the total bending (BENDNG) equaled the astronomical zenith angle.

Autolayering is again selected but now the parameters AVTRAT, TDIFF1, and TDIFF2 are supplied on Card 4 as 2.0, 50.0, and 50.0 respectively. The large values of TDIFF1 and TDIFF2 will generate a relatively small number of thick output layers. This layering is useful for initial or survey line-by-line calculations since the time of the calculation is related to the number of layers. More accurate calculations may require more layers: the user must experiment with different layerings to determine the minimum number of layers consistent with his accuracy requirements.

11. Goldman, A., Blatherwick, R.D., Murcray, F.J., Van Allen, J.W., Murcray, F.H., and Murcray, D.G. (1982) Atlas of stratospheric IR absorption spectra, Appl. Opt. 21:1163-1164.

Using a value of AVTRAT larger than 2.0 will also generate thick output layers. However, due to the layer to layer merging scheme used in FASCODE, layers generated by a value of AVTRAT greater than 2.0 may be inconsistent with FASCODE.

The user-supplied atmospheric profile is read in after Card 4. In this case, the temperature profile is from the U.S. Standard Atmosphere 1976 while the volume mixing ratios up to 50 km for the various gases, except CO₂, are from Smith¹² (see also Appendix A). Above the 50 km only a water vapor concentration is given; the mixing ratios for the "uniformly mixed gases" CO₂, N₂O, CO, CH₄, and O₂ revert to their default values. Note: the program does not check whether the atmosphere is in hydrostatic equilibrium.

Following the atmospheric profile are the slant path parameters in standard form. This path passes through a tangent height of 9.152 km. Next comes the internally-generated FASCODE output layer boundaries; note that the ratio of the Voigt halfwidths controls the layering up to 40 km. The rest of the output is straight forward and self-explanatory.

Case 3, shown in Table 4c, illustrates the use of user-supplied output layers, the NOZERO option, and of the short form of the output. On Card 1, IBND is set to the number of user-supplied output boundaries, 25 in this case. The altitudes are then read in after Card 3. The NOPRNT = 1 option suppresses the printing of the tables of the atmospheric profile and ray trace calculation. The NOZERO = 1 option preserves the amounts for all the molecules for all the layers. This option is important, for example, when calculating the radiance measured looking down from space, where the contribution from a high but sparse layer can be significant. The particular case run here applies to calculating weighting functions for temperature sounding from a satellite looking straight down from space. Note also that the program resets H1 from the input value 500 km to 100 km, which is the altitude of the highest boundary in the atmospheric profile.

The last case, shown in Table 4d, illustrates the use of H1, H2, and RANGE to describe the path. The program calculates ANGLE from H1, H2, and RANGE assuming no refraction, and then traces out the path using H1, H2, and ANGLE. Due to refraction the resultant RANGE is significantly larger than the input value. Also shown is the output on TAPE7 selected by the IPU=1 option on Card 1. This output is in a form suitable for direct input to FASCODE.

12. Smith, M.A.H. (1982) Compilation of Atmospheric Gas Concentration Profiles From 0 to 50 km, NASA TM-83289.

3.3 Program Structure

The program consists of a simple driver program, called FSCATM, and 20 subroutines. Table 5 lists the program units and their functions and Figure 20 shows the relationship among the principal ones. Each subroutine contains comment cards describing its function. The comments in ATMPATH contain a concise description of the program usage. The program is modular so that the user may easily modify it to suit any particular needs.

Table 5. Program Units and Their Functions

Program Unit	Function
FSCATM	Interface between FASCODE and ATMPATH
ATMCON	Block data: Initializes various program constants
ATMPATH	Main subroutine: Handles I/O
MLATMB	Block data: Stores reference profiles
MLATM	Model atmosphere: Sets up atmospheric profile
NSMDL	Non-standard model: Inputs user profiles
WATVAP	Calculates the water vapor number density for non-standard conditions
GEOINP	Reduces the input slant path parameters to the standard form: H1, H2, ANGLE, LEN
REDUCE	Eliminates slant path segments that extend about the highest profile altitude
FDBETA	Calculates angle given the input parameters H1, H2, BETA
EXPINT	Exponential interpolation
FNDHMN	Calculates HMIN = Minimum altitude along the path (Tangent altitude if any)
FINDSH	Finds the layer containing a given altitude
SCALHT	Calculates the scale height of the refractivity
ANDEX	Calculates the index of refraction at a given altitude
RADREF	Calculates the radius of curvature due to refraction
RFPATH	Drives the path calculation over all the layers
FILL	Sets up a profile extending from HMIN to HMAX
ALAYER	Calculates the path and the amounts through one layer
AUTLAY	Layers the atmosphere from HMIN to HMAX based on AVTRAT, TDIFF1, and TDIFF2
HALFWD	Calculates LORENTZ, DOPPLER, and VOIGT half-widths and ZETA given P, T, and VBAR

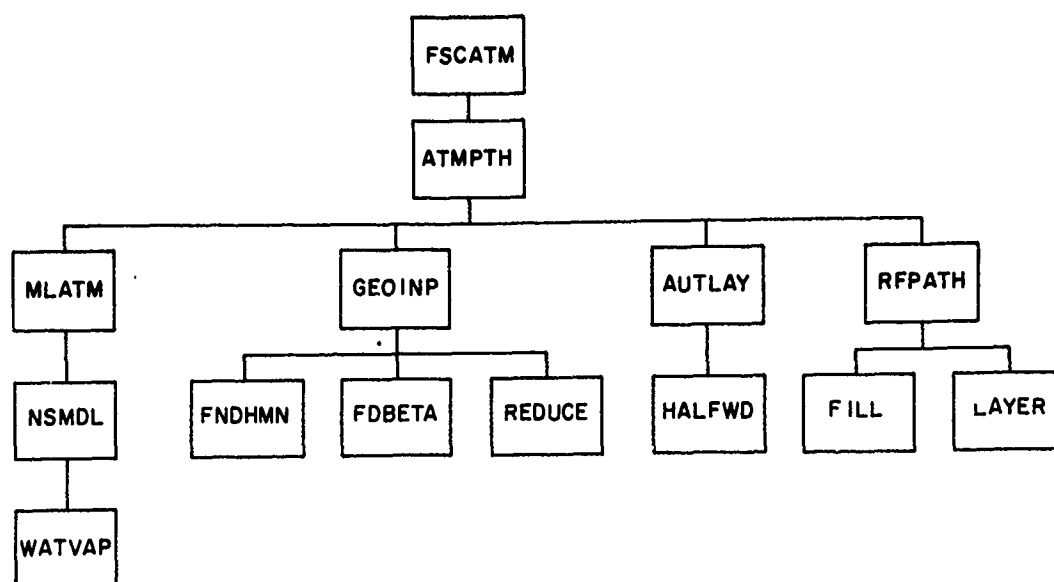


Figure 20. Structure Chart Showing the Major Subroutines

3.4 Portability

The program FSCATM runs on a CDC 6600 computer (a 60 bit word computer) with a FORTRAN 77 (FORTRAN V) compiler. It is also designed to be compatible with minor modifications with 32 bit word computer in single precision and with FORTRAN 66 (FORTRAN IV). To run on a 32 bit word computer, variables containing character data must be declared DOUBLE PRECISION (CHARACTER *8 will not work since some of these variables are carried in COMMON along with non-character variables). The required statements for this are supplied in the program with the characters 'C&' in Columns 1 to 3. To compile under CDC FORTRAN IV, all single quotes ' must be replaced with double quotes ". To convert the subroutine FSCATM to a stand-alone program, enable the statements in FSCATM with the characters 'CP' in Columns 1 and 2, and include the subroutines from ATMPH to HALFWD. The user must also supply subroutines DATE and TIME, which return the date and time in A8 format.

When the sample cases described in Section 3.2 are run on a 32 bit word computer in single precision, the results may be different in the third or fourth decimal place compared with the sample output. This precision is generally sufficient considering the accuracy of the models and of the data.

3.5 Availability

FSCATM is available as a part of the FASCOD1C package. This package includes the program FASCOD1C plus various other associated programs and sample input and output. The package is available on tape from

National Climatic Center, NOAA
Environmental Data Service
Federal Building
Asheville, NC 28801
(704)-258-2850, ex 682 (Ms Yolanda Goodge)

and presently costs \$98.00. The users guide for FASCOD1C is available from

S. A. Clough
AFGL/OPI
Hanscom AFB MA 01731

An earlier version of FSCATM, called FSCDATM, was distributed as a part of the FASCOD1B package. FSCATM is a revision of FSCDATM with a number of improvements and fixes. In particular, FSCDATM would not work properly on a 32 bit word computer in single precision for tangent paths. This bug has been fixed in FSCATM.

3.6 Errata for FSCATM

As distributed with FASCOD1C, FSCATM contained six known errors. The corrections are as follows:

1. Line 24740 (line 420 of ATMPPTH)

IF (VMIX(I).GT.0.0) DENSTY(K,1) = VMIX(K)*RHOBAR*1.0E-6

should read

IF (VMIX(K).GT.0.0) DENSTY(K,1) = VMIX(K)*RHOBAR*1.0E-6

2. After line 25300 (line 476 of ATMPPTH), insert

NLAYERS = 1

WN2L(1) = AMTAIR * VMIXN2 * 1.0 E-6

3. Line 25240 (line 488 of ATMPPTH)

1 (AMOUNT(K,1), K=1, KMAX)

should read

1 (AMOUNT(K,1), K=1, 7), WN2L(1), (AMOUNT(K,1), K=8, KMAX)

4. Lines 28540 to 28550 (lines 800 to 801 of ATMPH)

```
IF(IPUNCH.EQ.1) WRITE(IPU,70)(AMOUNT(K,L),K=1,KMAX)
70 FORMAT(1P8E10.2)
```

should read

```
IF(IPUNCH.NE.1) GO TO 470
WRITE(IPU,70)(AMOUNT(K,L),K=1,7),WN2L(L)
70 FORMAT (1P8E10.2)
IF(KMAX.GT.7)WRITE(IPU,70)(AMOUNT(K,L),K=8,KMAX)
```

5. In FORMAT statements 30, 35, and 37 of ATMPH, the '20X' should be changed to 'T20'.

6. Line 44970 (line 143 of ALAYER)

```
TPSUM(J) = TPSUM(J) + 0.5*DS*(PA+PB)
```

should read

```
TPSUM(J) = TPSUM(J) + 0.5*DS*(PA+PB)/GCAIR
```

Corrections 1 and 2 are required for the program to run a horizontal path properly. Corrections 3 and 4 are required to write the proper layer information to TAPE7. Correction 5 affects only the printed output of the total air amounts. Correction 6 fixes an error in the calculation of the average temperature for a very thin layer: most paths are unaffected by this error. These corrections have been incorporated into the listing contained in this report, with an '!' in column 74.

3.7 Program Listing

```

SUBROUTINE FSCATM                                020000
CP PROGRAM FSCATM                                CP020010
C*****                                           020020
C                                           020030
C FSCATM IS AN ATMOSPHERIC RAY TRACE PROGRAM.    020040
C IT CREATES AND FORMATS THE ATMOSPHERIC INPUTS FOR THE AFGL 020050
C LINE-BY-LINE TRANSMITTANCE/RADIANCE PROGRAM FASCODE. 020060
C                                           020070
C SEE THE COMMENTS IN SUBROUTINE ATMPH FOR DETAILED INSTRUCTIONS ON 020080
C THE USAGE OF THE ATMOSPHERIC INPUTS.          020090
C                                           020100
C TO CONVERT THE AIR MASS MODULE TO A STAND ALONE PROGRAM, 020110
C INCLUDE THE SUBROUTINES FROM FSCATM TO HALFWD, AND 020120
C ENABLE THE CARDS THAT BEGIN WITH 'CP '.      020130
C                                           020140
C TO RUN THE PROGRAM ON A 32 BIT WORD MACHINE, ENABLE THE CARDS 020150
C THAT BEGIN WITH 'C& '.                      020160
C                                           020170
C*****                                           020180
COMMON /PATHD/ PBAR(37),TBAR(37),AMOUNT(20,37),WN2L(37), 020190
C DVL(37),WTOTL(37),ALBL(37),ADBL(37),AVBL(37),H2OSL(37), 020200
C ICNTRL(37),ITYL(37),SECNTA(37),ALTB(37),ALTI(37),HT1,HT2 020210
COMMON /MAIN/ NWDFIL,KFILE,KPANEL,LINFIL,P0,TEMPO,NLAYRS, 020220
C H2OSLF,WTOT,ALBAR,ADBAR,AVBAR,AVFIX,LAYRFX,SECNT0, 020230
C SAMPLE,ALFALO,AVMASS 020240
C& DOUBLE PRECISION XID,SECANT,HMOLID,YID ,HMOL C&020250
COMMON /FILHOR/ XID(10),SECANT,PAVE,TAVE,HMOLID(20),WK(20),WN2, 020260
C DV,V1,V2,TBOUND,EMISIV,FSCDID(17),NMOL,LAYER, 020270
C Y11,YID(10) 020280
EQUIVALENCE (FSCDID(5),IEMIT) 020290
C& DOUBLE PRECISION HMOLS C&020300
COMMON /HMOLS/ HMOLS(20) 020310
COMMON /IFIL/ IRD,IPR,IPU 020320
COMMON /PARMT/ PI,DEG,GCAIR,RE,DELTAS,ZMIN,ZMAX,IMAX,IMOD,IBMAX, 020330
1 ICUTMX,IPATH,IMDDMX,IDIM,KDIM,KMXNDM,KMAX,NOPRNT 020340
C& DOUBLE PRECISION HDATE,HTIME C&020350
C*****IRD, IPP, IPU ARE UNIT NUMBERS FOR INPUT, OUTPUT, PUNCH 020360
CP DATA IRD/5/,IPR/6/,IPU/7/,IEMIT/0/ 020370
CP OPEN(UNIT=5,FILE='INPUT',STATUS='OLD') 020380
CP OPEN(UNIT=6,FILE='OUTPUT') 020390
CALL DATE(HDATE) 020400
CALL TIME(HTIME) 020410
WRITE(IPR,900) HDATE,HTIME 020420
900 FORMAT('1',20X,'*****PROGRAM FSCATM*****',A10,5X,A10,///) 020430
C***** 020440
CALL ATMPH(IEMIT) 020450
C***** 020460
SECANT = 1.0 020470
NMOL = KMAX 020480
DO 30 M=1,KMAX 020490
30 HMOLID(M)=HMOLS(M) 020500
RETURN 020510
CP STOP 020520
C 020530
END 020540

```

[illegible]

C THE PRINCIPAL OUTPUT CONSISTS OF THE INTEGRATED ABSORBER AMOUNTS 021150
 C FOR A SET OF LAYERS TO BE INPUT TO THE LINE-BY-LINE CALCULATION. 021160
 C THE NUMBER OF THESE LAYERS REPRESENTS A TRADEOFF BETWEEN ACCURACY. 021170
 C AND COMPUTATIONAL SPEED OF THE LINE-BY-LINE CALCULATION. THE 021180
 C USER HAS THE OPTION OF INPUTTING HIS OWN SET OF LAYER BOUNDARIES 021190
 C OR OF LETTING THE SUBROUTINE AUTLAY GENERATE THESE LAYERS 021200
 C AUTOMATICALLY. IF THE USER INPUTS HIS OWN BOUNDARIES, THEY NEED 021210
 C NOT FALL ON THE ATMOSPHERIC PROFILE BOUNDARIES OR INCLUDE THE 021220
 C PATH ENDPOINTS. IF AUTOMATIC LAYERING IS SELECTED, THE USER MAY 021230
 C SPECIFY THE MAXIMUM HALFWIDTH RATIO ACROSS A LAYER AND THE 021240
 C MAXIMUM TEMPERATURE DIFFERENCE ACROSS A LAYER. 021250
 C 021260
 C 021270
 C IT IS DIFFICULT TO SPECIFY APRIORI THE RELATIONSHIP BETWEEN 021280
 C THE NUMBER OF LAYERS AND THE ACCURACY: THE ACCURACY DEPENDS UPON 021290
 C SUCH FACTORS AS THE SPECTRAL REGION, THE DISTRIBUTION OF THE 021300
 C MOLECULES OF INTEREST, THE PARTICULAR PATH TAKEN, AND WHETHER 021310
 C TRANSMITTANCE OR RADIANCE IS CALCULATED. THE LAYERING CREATED 021320
 C BY THE DEFAULT VALUES OF AVTRAT (2.0) AND TDIFF1 (15.0 K) AND 021330
 C TDIFF2 (30.0 K) SHOULD BE CONSIDERED A POINT OF DEPARTURE FOR 021340
 C SUBSEQUENT CALCULATIONS. THE USER SHOULD THEN EXPERIMENT WITH 021350
 C DIFFERENT LAYERING UNTIL THE RESULTS ARE CONSISTENT WITH 021360
 C HIS ACCURACY REQUIREMENTS. 021370
 C 021380
 C TO SAVE COMPUTER TIME IN FASCOD1, THE LAYER AMOUNTS ARE ZEROED 021390
 C OUT WHEN 021400
 C 1. THE CUMULATIVE AMOUNT FOR THAT LAYER AND ABOVE IS LESS 021410
 C THAN 0.1 PERCENT OF THE TOTAL, 021420
 C AND 021430
 C 2. A. TRANSMITTANCE IS CALCULATED (IEMIT = 0) 021440
 C OR 021450
 C B. RADIANCE IS CALCULATED (IEMIT = 1) AND THE PATH IS 021460
 C LOOKING UP (ICNTRL = 3) 021470
 C Q2 IS NOT CONSIDERED IN THIS SCHEME. IF THE ABSORBER 021480
 C FOR A LAYER FOR ALL THE MOLECULES (EXCEPT Q2) ARE ZEROED 021490
 C OUT, THEN THAT LAYER AND THOSE ABOVE ARE ELIMINATED 021500
 C 021510
 C TO CALCULATE THE AMOUNTS FOR THE TRACE GASES (MOLECULES 8 THROUGH 021520
 C 20) THE USER MUST INCREASE KMAX ON CARD 1 AND READ IN AN 021530
 C ATMOSPHERIC PROFILE (MODEL = 7) INCLUDING THE VOLUME MIXING RATIOS 021540
 C OF THE ADDITIONAL MOLECULES. 021550
 C 021560
 C ----- 021570
 C CONTROL CARDS: 021580
 C 021590
 C FOUR CONTROL CARDS CONTROL THE OPERATION OF THE PROGRAM WHILE 021600
 C OTHER CARDS MAY BE READ IN TO DEFINE NON-STANDARD CONDITIONS. THE 021610
 C FORMATS OF THESE CARDS AND THE MEANING OF THE PARAMETERS ARE 021620
 C DESCRIBED AS FOLLOWS: 021630
 C 021640
 C CONTROL CARD 1: MODEL, ITYPE, IBND, NOZERO, NOPRNT, KMAX, 021650
 C IPUNCH, RE 021660
 C (715,5X,F10.4) 021670
 C MODEL = 0: USER SUPPLIED HORIZONTAL PATH PARAMETERS 021680
 C 1: TROPICAL MODEL ATMOSPHERE 021690
 C 2: MIDLATITUDE SUMMER 021700
 C 3: MIDLATITUDE WINTER 021710
 C 4: SUBARCTIC SUMMER 021720
 C 5: SUBARCTIC WINTER 021730
 C 6: U.S. STANDARD, 1962 021740

C		7: USER SUPPLIED ATMOSPHERIC PROFILE	021750
C	ITYPE =	1: HORIZONTAL PATH (CONSTANT PRESSURE)	021760
C		2: SLANT PATH FROM H1 TO H2	021770
C		3: SLANT PATH FROM H1 TO SPACE	021780
C	IBND	NUMBER OF BOUNDARY ALTITUDES FOR THE FASCODE1	021790
C		LAYERS: IF IBND GT 0, USER SUPPLIES BOUNDARIES	021800
C		IF IBND = 0, AUTO LAYERING IS SELECTED	021810
C	NOZERO =	1: SUPPRESSES ZEROING OF SMALL AMOUNTS.	021820
C		DEFAULT = 0	021830
C	NOPRNT =	1: SELECTS SHORT PRINTOUT. DEFAULT = 0	021840
C	KMAX	NUMBER OF MOLECULAR SPECIES. DEFAULT = 7	021850
C		IF KMAX LT 0, A RAY TRACE IS DONE BUT NO AMOUNTS	021860
C		ARE CALCULATED	021870
C	IPUNCH =	1: WRITE LAYER AMOUNTS TO UNIT IPU=7. DEFAULT = 0	021880
C	RE	RADIUS OF THE EARTH. DEFAULTS:	021890
C		MODEL = 1, RE = 6378.39 KM	021900
C		2,3,6,7, RE = 6371.23 KM	021910
C		4,5, RE = 6356.91 KM	021920
C			021930
C		THE FORMATS FOR THE REMAINING CONTROL CARDS ARE DIFFERENT	021940
C		DEPENDING ON WHETHER THE PATH IS HORIZONTAL (ITYPE = 1)	021950
C		OR SLANT (ITYPE = 2 OR 3)	021960
C			021970
C			021980
C			021990
C		FOR A SLANT PATH (ITYPE = 2 OR 3):	022000
C			022010
C		CONTROL CARD 2: H1,H2,ANGLE,RANGE,BETA,LEN	022020
C		(5F10.4,15)	022030
C	H1	ALTITUDE OF THE OBSERVER OR RECIEVER (KM)	022040
C	H2	ALTITUDE OF THE OTHER ENDPOINT OF THE PATH (KM):	022050
C	ANGLE	ZENITH ANGLE AT H1 (DEGREES)	022060
C	RANGE	LENGTH OF THE PATH FROM H1 TO H2 (KM):	022070
C	BETA	EARTH CENTERED ANGLE FOR THE PATH H1 TO H2 (DEG)	022080
C	LEN	=0, SHORT PATH; =1, LONG PATH THROUGH A TANGENT:	022090
C		HEIGHT. LEN IS USED ONLY WHEN ANGLE IS GT 90.0	022100
C		AND H1 IS GT H2. DEFAULT = 0.	022110
C			022120
C		ONLY THREE OF THE FIRST FIVE PARAMETERS NEED BE SPECIFIED;	022130
C		FOR EXAMPLE, H1, H2, ANGLE. OR H1, H2, BETA. OR H1, ANGLE, RANGE.	022140
C		SEE THE COMMENTS IN THE SUBROUTINE GEOINP OR SEE REFERENCE (2)	022150
C		FOR MORE DETAILS ON THE POSSIBLE COMBINATIONS OF THESE PARAMETERS	022160
C			022170
C		CONTROL CARD 3: V1, V2	022180
C		(2F10.3)	022190
C	V1,V2	INITIAL AND FINAL WAVENUMBERS FOR USE	022200
C		IN CALCULATING THE DOPPLER HALFWIDTH USED IN	022210
C		CREATING THE FASCODE LAYERS AND IN CALCULATING	022220
C		THE INDEX OF REFRACTION (CM-1)	022230
C			022240
C		CONTROL CARD 4: (LAYERING)	022250
C			022260
C		IF IBND = 0 (AUTOLAYERING SELECTED)	022270
C			022280
C		AVTRAT,TDIFF1,TDIFF2 (3F10.3)	022290
C		AVTRAT = MAX VOIGT WIDTH RATIO ACROSS A LAYER	022300
C		DEFAULT = 2.0	022310
C		TDIFF1 = MAX TEMP DIFFERENCE (K) ACROSS A LAYER AT HMIN	022320
C		(=LOWEST ALTITUDE ALONG THE PATH).	022330
C		DEFAULT = 15.0 K	022340

```

C          TDIFF2 = MAX TEMP DIFFERENCE (K) ACROSS A LAYER AT HMAX      022350
C          (=HIGHEST ALTITUDE ALONG THE PATH).                        022360
C          DEFAULT = 30.0 K                                           022370
C
C          IF IBND NE 0 (USER SUPPLIED FASCOD1 LAYER BOUNDARIES)      022380
C
C          (ZBND(IB),IB=1,IBND) (8F10.3)                             022390
C          ZBND      ALTITUDES OF FASCOD1 LAYER BOUNDARIES           022400
C
C          IF MODEL = 7, THE INPUT ATMOSPHERIC PROFILE IS READ IN AFTER 022410
C          CONTROL CARD 4 IN THE FOLLOWING FORMAT:                     022420
C
C          IMOD, HEADER (15./,3A8)                                     022430
C          IMOD = NUMBER OF LEVELS IN THE PROFILE                     022440
C          HEADER = 24 CHARACTER HEADER DESCRIBING THE PROFILE       022450
C
C          Z,P,T,TD,RH,PPH2O,DENH2O,AMSMIX (8F10.3)                 022460
C          (VMIX(K),K=1,KMAX) (8E10.3)                               022470
C          TWO (OR MORE) CARD IMAGES FOR EACH OF THE IMOD            022480
C          LEVELS. SEE COMMENTS FOR THE SUBROUTINE NSMDL             022490
C          REGARDING THE DEFINITIONS AND USAGES OF THESE              022500
C          PARAMETERS.                                                 022510
C
C-----
C
C          FOR A HORIZONTAL PATH (.TYPE = 1):                          022520
C          CONTROL CARD 2:                                             022530
C          FOR MODEL = 1 TO 7:                                         022540
C          Z,RANGE (2F10.3)                                           022550
C
C          FOR MODEL = 0:                                              022560
C          RANGE,P,T,TD,RH,PPH2O,DENH2O,AMSMIX (8F10.3)             022570
C          (VMIX(K),K=1,KMAX) (8E10.3)                               022580
C          WHERE Z AND RANGE ARE THE ALTITUDE AND RANGE OF            022590
C          THE PATH, BOTH IN KM. FOR MODEL = 1 TO 7, THE              022600
C          PRESSURE, TEMPERATURE, AND DENSITIES ARE                  022610
C          INTERPOLATED FROM THE MODEL ATMOSPHERE. FOR               022620
C          MODEL = 0, SEE THE NOTES FOR THE SUBROUTINE               022630
C          NSMDL FOR THE DEFINITIONS AND USAGES OF THE               022640
C          PARAMETERS IN THIS CASE. IF THE VOLUME MIXING             022650
C          RATIO OF O3 IS NOT SUPPLIED FOR MODEL = 0, IT IS          022660
C          COMPUTED USING A VALUE FOR THE VOLUME                     022670
C          MIXING RATIO OF 40.E-9.                                    022680
C
C          CONTROL CARDS 3 AND 4: NOT USED                             022690
C
C          FOR MODEL 7, THE INPUT ATMOSPHERIC PROFILE IS READ IN AFTER 022700
C          CONTROL CARD 2 AS FOR A SLANT PATH.                        022710
C
C-----
C
C          OUTPUT :                                                    022720
C
C          THE PRINTED OUTPUT IS ON FILE IPR (DEFAULT=6). SELECTING   022730
C          NOPPNT=1 SUPPRESSES THE PRINTING OF THE ATMOSPHERIC PROFILES 022740
C          AND THE LAYER-BY-LAYER RESULTS FOR THE REFRACTED PATH.     022750
C          IF IPUNCH = 1, THEN THE FASCOD1 INPUT DATA IS ALSO PUT ON FILE 022760
C          IPU (DEFAULT=7) AND CONSISTS OF A SINGLE CARD IMAGE GIVING THE 022770
C          NUMBER OF LAYERS LMAX AND A 70 CHARACTER FIELD DESCRIBING THE 022780
C          PROFILE AND THE PATH, FOLLOWED BY TWO (OR MORE) CARD IMAGES FOR 022790
C

```

```

C
C      EACH OF THE LMAX LAYERS
C
C      CARD 1: LMAX,LABEL (15,5X,A70)
C      LMAX = NUMBER OF FASCOD1 LAYERS, MAY DIFFER FROM
C      IBND DEPENDING ON THE PATH.
C      LABEL = 70 CHARACTER FIELD.
C
C      CARD 2: PAVE,TAVE,ICNTRL,LAYRID
C      (2F10.4,10X,15,25X,A20)
C      PAVE = AVERAGE PRESSURE (MB)
C      TAVE = AVERAGE TEMPERATURE (K)
C      ICNTRL : IF THE PATH DOES NOT GO THROUGH A TANGENT HEIGHT,
C      IF H1.LT.H2 ICNTRL = 3
C      IF H1.GT.H2 ICNTRL = 1
C      IF THE PATH GOES THROUGH A TANGENT HEIGHT, THEN
C      FOR THE LAYERS FROM THE TANGENT HEIGHT TO
C      MIN(H1,H2), ICNTRL = 2
C      FOR THE LAYERS (IF ANY) FROM MIN(H1,H2)
C      TO H1, ICNTRL = 1
C      FOR THE LAYERS (IF ANY) FROM MIN(H1,H2)
C      TO H2, ICNTRL = 3
C      FOR A HORIZONTAL PATH, ICNTRL = 0
C      LAYRID: 20 CHARACTER FIELD GIVING THE BOUNDARY
C      ALTITUDES (ITYPE 2 OR 3) OR PANGE AND
C      ALTITUDE (ITYPE 1)
C
C      CARD 3: (AMOUNT(K),K=1,KMAX)
C      (1P8E10.2)
C      AMOUNT(K) INTEGRATED ABSORBER AMOUNT FOR THE K'TH
C      MOLECULAR SPECIES (MOLECULES CM-2)
C
C      CARDS 2 AND 3 ARE REPEATED UNTIL LMAX LAYERS ARE SPECIFIED.
C
C-----
C
C      REFERENCES:
C
C      (1) FASCOD1 - A USERS' GUIDE (AVAILABLE FROM S.A. CLOUGH AT
C      THE ABOVE ADDRESS)
C      SEE ALSO:
C      FASCODE - FAST ATMOSPHERIC SIGNATURE CODE
C      (SPECTRAL TRANSMITTANCE AND RADIANCE)
C      AFGL-TR-78-008
C
C      (2) FSCATM - A FORTRAN PROGRAM TO CALCULATE AIR MASS FOR
C      INFRARED RADIATIVE TRANSFER (AFGL REPORT- IN PREPARATION)
C
C      (3) ATMOSPHERIC TRANSMITTANCE/RADIANCE:
C      COMPUTER CODE LOWTRAN 5
C      AFGL-TR-80-0067
C
C      (4) OPTICAL PROPERTIES OF THE ATMOSPHERE (THIRD EDITION)
C      AFGL-TR-72-0497
C
C*****
C
C      COMMON /IFIL/ IHD,IPR,IPU
C      COMMON /PARMT/ PI,DEG,GCAIR,RE,DEL,S,ZMIN,ZMAX,IMAX,IMOD,IBMAX,

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```

022950
022960
022970
022980
022990
023000
023010
023020
023030
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023090
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023540

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1      IOUTMX,IPATH,IMODMX,IDIM,KDIM,KMXNOM,KMAX,NOPRNT      023550
COMMON /CONSTN/ PZERO,TZERO,AVOGAD,ALOSMT,GASCON,PLANK,BOLTZ, 023560
1      CLIGHT,ADCON,ALZERO,AVMWT,AIRMT,AMWT(20),VMIXST(20),VMIXN2 023570
C&    DOUBLE PRECISION HMOD      C&023580
COMMON HMOD(3),ZM(50),PM(50),TM(50),RFNDXM(50),DENM(20,50) 023590
COMMON ZP(71),PP(71),TP(71),RFNDXP(71),SP(71), 023600
1      PPSUM(71),TPSUM(71),RHOPSM(71),DENP(20,71),AMTP(20,71) 023610
COMMON Z(71),P(71),T(71),RFNDX(71),DENSTY(20,71) 023620
C&    DOUBLE PRECISION HMOLS      C&023630
COMMON /HMOLS/ HMOLS(20) 023640
COMMON /PATHO/ PBAR(37),TBAR(37),AMOUNT(20,37),WN2L(37), 023650
C      DVL(37),WTOTL(37),ALBL(37),ACDL(37),AVBL(37),H2OSL(37), 023660
C      ICNTRL(37),ITYL(37),SECNTA(37),ALTB(37),ALTT(37),HT1,HT2 023670
COMMON /MAIN/ NWDFIL,KFILE,KPANEL,LINFIL,PO,TEMPO,NLAYRS, 023680
C      H2OSLF,WTOT,ALBAR,ADBAR,AVBAR,AVFIX,LAYRFX,SECNT0, 023690
C      SAMPLE,ALFALO,AVMASS 023700
COMMON /BNDRY/ ZBND(34),PBND(34),TEND(34),ALORNZ(34),ADOPP(34), 023710
1      AVOIGT(34) 023720
COMMON /ZOUTP/ ZOUT(37),SOUT(37),RHOSUM(37),AMTTOT(20),AMTCUM(20), 023730
C      ISKIP(20) 023740
DIMENSION VMIX(20) 023750
DIMENSION XZM(6312),XPBAR(1258),XZOUT(171) 023760
EQUIVALENCE (ZM(1),XZM(1)),(PBAR(1),XPBAR(1)),(ZOUT(1),XZOUT(1)) 023770
C&    DOUBLE PRECISION HORIZ      C&023780
DIMENSION HORIZ(3) 023790
DATA AVRATS/2.0/,TDIFS/15.0/,TDIFS/30.0/ 023800
DATA HORIZ/8HHORIZONT, 8HAL PATH, 8H / 023810
DATA HT1HRZ/4H AT /,HT2HRZ/4H KN /,HT1SLT/4H TO /,HT2SLT/4H KM / 023820
DATA IERROR/0/ 023830
C*****IAMT = 1:CALCULATE AMOUNTS, IAMT = 2:DO NOT CALCULATE AMOUNTS 023840
DATA IAMT/1/ 023850
C*****O3VMIX IS THE MEAN SURFACE VOLUME MIXING RATIO OF OZONE, 023860
C*****PARTS PER MILLION, FROM U. S. STANDARD ATMOSPHERE, 1976 023870
DATA O3VMIX/40.0E-3/ 023880
C*****AIRMS1 IS ONE AIRMASS OR THE TOTAL AMOUNT FOR A VERTICAL PATH 023890
C*****FROM GROUND TO SPACE 023900
DATA AIRMS1/2.153E25/ 023910
PI = ASIN(1.0)*2.0 023920
DEG = 180.0/PI 023930
C*****GCAIR IS THE GAS CONSTANT FOR RHO IN MOL CM(-3), P IN MB, AND 023940
C*****T IN K 023950
GCAIR = 1.0E-3*GASCON/AVOGAD 023960
C*****ADCON IS THE CONSTANT FOR THE DOPPLER HALFWIDTH 023970
ADCON = SORT(2.0*ALOG(2.0)*GASCON/CLIGHT**2) 023980
C*****ZERO OUT COMMON BLOCKS 023990
NXZM = IMODMX*(4+KDIM)+IDIM*(12+3*KDIM) 024000
NXPBAR = IOUTMX*(14+KDIM) 024010
NXZOUT = IOUTMX*3+KDIM*3 024020
DO 90 N=1,NXZM 024030
90 XZM(N) = 0.0 024040
DO 91 N=1,NXPBAR 024050
91 XPBAR(N) = 0.0 024060
DO 92 N=1,NXZOUT 024070
92 XZOUT(N) = 0.0 024080
C***** 024090
C***** 024100
C*****READ CONTROL CARD 1 024110
READ(IRD,20) MODEL,ITYPE,IGHD,NOZERO,NOPRNT,KMAX,IPUNCH,RE 024120
20 FORMAT(7I5,5X,F10.3) 024130
WRITE(IPR,21) 024140

```



```

21 FORMAT(' CONTROL CARD 1: MODEL AND OPTIONS ')
WRITE(IPR,22) MODEL,ITYPE,IBND,NOZERO,NOPRNT,KMAX,IPUNCH,RE
22 FORMAT(/,10X,'MODEL' = ,15/,10X,'ITYPE' = ,15/,
1 10X,'IBND' = ,15/,10X,'NOZERO' = ,15/,
2 10X,'NOPRNT' = ,15/,10X,'KMAX' = ,15/,
3 10X,'IPUNCH' = ,15/,
3 10X,'RE' = ,F10.3,' KM')
M = MODEL
IF(ITYPE.LT.1 .OR. ITYPE.GT.3) GO TO 900
IF(M.LT.0 .OR. M.GT.7) GO TO 900
IF(IBND.GT.IBMAX) GO TO 900
IF(KMAX.GT.KDIM) GO TO 900
IF(KMAX.EQ.0) KMAX = KMXNOM
IF(IPUNCH.EQ.1) OPEN(UNIT=IPU,FILE='TAPE7')
IF(RE.NE.0.0) GO TO 95
RE = 6371.23
IF(M.EQ.1) RE = 6378.39
IF(M.EQ.4 .OR. M.EQ.5) PE = 6356.91
95 CONTINUE
WRITE(IPR,24)
24 FORMAT(/,,' CONTROL CARD 1 PARAMETERS WITH DEFAULTS:')
WRITE(IPR,22) MODEL,ITYPE,IBND,NOZERO,NOPRNT,KMAX,IPUNCH,RE
IF(ITYPE.NE.1) GO TO 200
C*****
C*****
C*****HORIZONTAL PATH SELECTED
C*****
C*****
WRITE(IPR,25)
25 FORMAT(/,,' HORIZONTAL PATH SELECTED';
DO 103 I=1,3
HMOD(I) = HORIZ(I)
103 CONTINUE
IF(M.NE.0) GO TO 120
C*****READ IN PARAMETERS FOR A HORIZONTAL PATH, MODEL 0
READ(IRD,26) RANGE,PH,TH,TD,RH,PPH20,DENH20,AMSMIX,
1 (VMIX(K),K=1,KMAX)
26 FORMAT(8F10.3/, (8E10.3))
WRITE(IPR,27) RANGE,PH,TH,TD,RH,PPH20,DENH20,AMSMIX, (HMOLS(K),
1 K=1,KMAX)
27 FORMAT(/,,' ECHO INPUT PARAMETERS FOR MODEL 0',/,
1 10X,'RANGE' = ,F10.3,' KM',/,10X,'P' = ,F10.3,' MB',/,
2 10X,'T' = ,F10.3,' K',/,10X,'DEW PT' = ,F10.3,' C',/,
3 10X,'REL HUM' = ,F10.3,' %',/,10X,'PART PR' = ,F10.3,' MB',/,
4 10X,'MASS DEN' = ,F10.3,' GM/M3',/,
5 10X,'MASS MIX' = ,F10.3,' GM/KG',/,
6 40X,'VOLUME MIXING RATIO ( PARTS PER MILLION)',/,
7 10X,'8A10)
WRITE(IPR,28) (VMIX(K),K=1,KMAX)
28 FORMAT(10X,1P6E10.3)
ZH = -9.9.0
RHOBAR = ALOSMT*(PH/PZERO)*(TZERO/TH)
DENSTY(1,1) = 0.0
IF(VMIX(1).EQ.0.0) CALL WATVAP(PH,TH,TD,RH,PPH20,DENH20,
1 AMSMIX,DENSTY(1,1))
IF(VMIX(1).GT.0.0) DENSTY(1,1) = VMIX(1)*RHOBAR*1.0E-6
DO 105 K=2,KMAX
DENSTY(K,1) = 0.0
IF(VMIX(K).EQ.0.0) DENSTY(K,1) = VMIX(K)*RHOBAR*1.0E-6
IF(VMIX(K).GT.0.0) DENSTY(K,1) = VMIX(K)*RHOBAR*1.0E-6

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105 CONTINUE
IF(VMIX(3).EQ.0.0) DENSTY(3,1) = O3VMIX*RHOBAR*1.0E-6
WRITE(IPR,29) RANGE, PH, TH, (HMOLS(K), K=1, KMAX)
29 FORMAT(///, ' PARAMETERS FOR A HORIZONTAL PATH, MODEL 0: ', //
1 10X, 'RANGE = ', F10.3, ' KM', //, 10X, 'P = ', F10.3, ' KM', //,
2 10X, 'T = ', F10.3, ' K', //,
3 10X, 'DENSITY ', T26, 'AIR', (T33, 8A10))
WRITE(IPR,30) RHOBAR, (DENSTY(K,1), K=1, KMAX)
30 FORMAT(T63, '(MOL CM-3)', //, (T20, 1PE10.3, (T30, 8E10.3)))
GO TO 160
C*****MODEL 1 TO 7
120 CONTINUE
C*****READ IN CONTROL CARD 2
READ(IRD,31) ZH, RANGE
31 FORMAT(F10.3, F10.3)
WRITE(IPR,32) ZH, RANGE
32 FORMAT(///, ' CONTROL CARD 2: ', //, 10X, 'Z = ', F10.3, ' KM', //,
1 10X, 'RANGE = ', F10.3, ' KM')
C*****SET UP THE ATMOSPHERIC PROFILE
CALL MLATM(M)
C*****INTERPOLATE ATMOSPHERIC PROFILE DENSITIES TO ZH
DO 130 IM= 2, IMOD
IF(ZH.LT. ZM(IM)) GO TO 140
130 CONTINUE
IM = IMOD
140 CONTINUE
A = (ZH-ZM(IM-1))/(ZM(IM)-ZM(IM-1))
CALL EXPINT(PH, PM(IM-1), PM(IM), A)
TH = TM(IM-1) + (TM(IM) - TM(IM-1)) * A
RHOBAR = ALOSMT * PH + TZERO / (PZERO * TH)
DO 150 K=1, KMAX
CALL EXPINT(DENSTY(K,1), DENM(K, IM-1), DENM(K, IM), A)
150 CONTINUE
WRITE(IPR,34) HMOD, ZH, PH, TH, (HMOLS(K), K=1, KMAX)
34 FORMAT(///, ' PRESSURE, TEMPERATURE, AND DENSITIES INTERPOLATED',
1 ' FROM THE FOLLOWING ATMOSPHERIC MODEL: ', //, 10X, 3A8, //
2 10X, 'Z = ', F10.3, ' KM', //, 10X, 'P = ', F10.3, ' MB', //,
3 10X, 'T = ', F10.3, ' K', //,
4 10X, 'DENSITIES : ', T26, 'AIR', (T30, 8A10))
WRITE(IPR,35) RHOBAR, (DENSTY(K,1), K=1, KMAX)
35 FORMAT(T63, '(MOL CM-3)', //, T20, 1PE10.3, (T30, 8E10.3))
160 CONTINUE
C*****COMPUTE AMOUNTS FOR A HORIZONTAL PATH
DO 170 K=1, KMAX
AMOUNT(K,1) = DENSTY(K,1) * RANGE * 1.0E+5
170 CONTINUE
AMTA!P = RHOBAR * RANGE * 1.0E-5
WRITE(IPR,36) HMOD, ZH, PH, TH, RANGE, (HMOLS(K), K=1, KMAX)
36 FORMAT(//, ' SINGLE LAYER INPUT TO FASCOD1', //, 10X, 'MODEL = ', 3A8, //,
1 10X, 'Z = ', F10.3, ' KM', //, 10X, 'P = ', F10.3, ' MB', //,
2 10X, 'T = ', F10.3, ' K', //, 10X, 'RANGE = ', F10.3, ' KM', //,
4 10X, 'AMOUNTS: ', T26, 'AIR', (T30, 8A10))
WRITE(IPR,37) AMTAIR, (AMOUNT(K,1), K=1, KMAX)
37 FORMAT(T63, '(MOL CM-2)', //, T20, 1PE10.2, (T30, 8E10.2))
ICNTRL(1)=0
LMAX = 1
NLAYS = 1
WN2L(1) = AMTAIR * VMIXN2 * 1.0E-6
PBAR(1)=PH
TBAR(1)=TH

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ALTB(1)=RANGE	025330
ZOUT(1)=ZH	025340
SECNTA(1)=1.	025350
ALTT(1)=ZH	025360
HT1 = HT1HRZ	025370
HT2 = HT2HRZ	025380
IF(IPUNCH.EQ.1) WRITE(IPU,38) LMAX,HMOD	025390
38 FORMAT(15,5X,3A8)	025400
IF(IPUNCH.EQ.1) WRITE(IPU,39) PH,TH,ICNTRL(1),RANGE,ZH,	025410
1 (AMOUNT(K,1),K=1,7),WN2L(1),(AMOUNT(K,1),K=8,KMAX)	025420
39 FORMAT(2F10.4,10X,15,25X,F7.2,' A',F7.2,' KM',/,	025430
1 (1PBE10.2))	025440
RETURN	025450
C*****	025460
C*****	025470
C*****SLANT PATH SELECTED	025480
C*****	025490
C*****	025500
200 CONTINUE	025510
C*****ITYPE = 2 OR 3: SLANT PATH THROUGH THE ATMOSPHERE	025520
WRITE(IPR,40) ITYPE	025530
40 FORMAT(///,' SLANT PATH SELECTED, ITYPE = ',I5)	025540
C***** READ IN CONTROL CARD 2 CONTAINING SLANT PATH PARAMETERS	025550
READ(IRD,46) H1,H2,ANGLE,RANGE,BETA,LEN	025560
46 FORMAT(5F10.4,I5)	025570
WRITE(IPR,48) H1,H2,ANGLE,RANGE,BETA,LEN	025580
48 FORMAT(///,' CONTROL CARD 2: SLANT PATH PARAMETERS',/,	025590
1 10X,'H1' = ',F10.4,' KM',/,10X,'H2' = ',F10.4,' KM',/,	025600
2 10X,'ANGLE' = ',F10.4,' DEG',/,10X,'RANGE' = ',F10.4,' KM',/,	025610
3 10X,'BETA' = ',F10.4,' DEG',/,10X,'LEN' = ',I10)	025620
C*****READ IN CONTROL CARD 3 GIVING THE FREQUENCY RANGE IN WAVENUMBERS	025630
READ(IRD,50) V1,V2	025640
50 FORMAT(2F10.3)	025650
VBAR = 0.5*(V1+V2)	025660
WRITE(IPR,51) V1,V2,VBAR	025670
51 FORMAT(///,' CONTROL CARD 3',/,10X,'V1' = ',F10.3,' CM-1',/,	025680
1 10X,'V2' = ',F10.3,' CM-1',/,10X,'VBAR' = ',F10.3,' CM-1')	025690
C*****GENERATE OR READ IN FASCOD1 BOUNDARY LAYERS	025700
IF(IBND.NE.0) GO TO 210	025710
C*****SELECT AUTOMATIC LAYERING	025720
READ(IRD,56) AVTRAT,TDIFF1,TDIFF2	025730
56 FORMAT(3F10.3)	025740
IF(AVTRAT.EQ.0.0) AVTRAT = AVTRATS	025750
IF(TDIFF1.EQ.0.0) TDIFF1 = TDIF1S	025760
IF(TDIFF2.EQ.0.0) TDIFF2 = TDIF2S	025770
WRITE(IPR,57) AVTRAT,TDIFF1,TDIFF2	025780
57 FORMAT(///,' AUTOLAYERING SELECTED',/,	025790
1 10X,'AVTRAT' = ',F8.2',/,10X,'TDIFF1' = ',F8.2',/,	025800
2 10X,'TDIFF2' = ',F8.2)	025810
IF(AVTRAT.LE.1.0 .OR. TDIFF1.LE.0.0 .OR. TDIFF2.LE.0.0) GO TO 906	025820
GO TO 220	025830
210 CONTINUE	025840
C*****READ IN FASCOD1 BOUNDARY LAYERS	025850
READ(IRD,58) (ZBND(IB),IB=1,IBND)	025860
58 FORMAT(8F10.3)	025870
WRITE(IPR,59) (IB,ZBND(IB),IB=1,IBND,	025880
59 FORMAT(///,' USER DEFINED BOUNDARIES FOR FASCOD1 LAYERS',/,	025890
1 10X,'I',4X,'Z (KM)',/,/(10X,I2,F10.4))	025900
IF(ZBND(1).LT.0) GO TO 902	025910
DO 215 IB=2,IBND	025920

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      IF(ZBND(IB).LE.ZBND(IB-1)) GO TO 902
215 CONTINUE
220 CONTINUE
C*****SET UP ATMOSPHERIC PROFILE
      CALL MLATM(M)
C*****COMPUTE THE REFRACTIVE INDEX PROFILE
C*****RFNDXM IS 1.0-INDEX
C*****EQUATION FOR RFNDXM IS FROM LOWTRAN (REF 3)
      DO 225 IM=1,IMOD
        PPH20 = DENM(1,IM)*PZERO*TM(IM)/(TZERO*ALOSMT)
        RFNDXM(IM) = ((77.46+0.459E-8*VBAR**2)*PM(IM)/TM(IM)
1          -(PPH20/1013.0)*(43.49-0.347E-8*VBAR**2))*1.0E-6
225 CONTINUE
C*****PRINT ATMOSPHERIC PROFILE
      WRITE(IPR,52) M,HMOD
      52 FORMAT('ATMOSPHERIC PROFILE SELECTED IS: M = ',I3,5X, 3A8)
      IF(NOPRNT.NE.0) GO TO 230
      WRITE(IPR,53) (HMOLS(K),K=1,KMAX)
      53 FORMAT(/,T5,'I',T12,'Z',T22,'P',T32,'T',T38,'REFRACT',
1      T70,'DENSITY (MOLS CM-3)',/,
2      T38,'INDEX+1',T50,/,
3      T11,'(KM)',T21,'(MB)',T31,'(K)',T38,'*1.0E6',
4      T50,'AIR',(T55,8A9))
      WRITE(IPR,55)
      55 FORMAT(/)
      DO 228 IM=1,IMOD
        DENAIR = ALOSMT*(PM(IM)/PZERO)*(TZERO/TM(IM))
        WRITE(IPR,54) IM,ZM(IM),PM(IM),TM(IM),RFNDXM(IM),DENAIR,
1      (DENM(K,IM),K=1,KMAX)
      54 FORMAT(I4,3F10.3,6PF10.3,1P9E9.2,/, (53X,1P8E9.2))
228 CONTINUE
230 CONTINUE
C*****REDUCE SLANT PATH PARAMETERS TO STANDARD FORM
      CALL GEONP(H1,H2,ANGLE,RANGE,BETA,ITYPE,LEN,HMIN,PHI,IERROR)
      IF(IERROR.NE.0) GO TO 904
C*****SET UP FASCOD1 LAYER BOUNDARIES
      IF(IBND.NE.0) GO TO 235
C*****AUTOMATIC LAYERING SELECTED
      HMAX = A*MAX1(H1,H2)
      CALL AUTLAY(HMIN,HMAX,VBAR,AVTRAT,TDIFF1,TDIFF2,IBND,IERROR)
      GO TO 238
235 CONTINUE
C*****USER SUPPLIED LAYERING
      WRITE(IPR,80)
      80 FORMAT(///,'HALFWIDTH INFORMATION ON THE USER SUPPLIED ',
1      'FASCOD1 BOUNDARIES',/, 'THE FOLLOWING VALUES ARE ASSUMED:')
      DO 237 IB=1,IBND
        CALL HALFWID(ZBND(IB),VBAR,PBND(IB),TBND(IB),ALORNZ(IB),ADOPP(IB),
1      AVOIGT(IB))
237 CONTINUE
238 CONTINUE
      WRITE(IPR,82) ALZERO,AVMWT,VBAR
      82 FORMAT(10X,'ALZERO = ',F9.3,' CM-1 = AVERAGE LORENTZ WIDTH ',
1      'AT STP',/,
2      10X,'AVMWT = ',F8.2,' = AVERAGE MOLECULAR WEIGHT',/,
3      10X,'VBAR = ',F8.2,' CM-1 = AVERAGE WAVENUMBER',///,
4      T5,'I',T12,'Z',T22,'P',T32,'T',T38,'LORENTZ',
5      T49,'DOPPLER',T61,'ZETA',T70,'VOIGT',T80,'VOIGT',T90,'TEMP',/,
6      T11,'(KM)',T21,'(MB)',T31,'(K)',T40,'(CM-1)',
7      T50,'(CM-1)',T70,'(CM-1)',T80,'RATIO',T90,'DIFF (K)',/)

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DO 239 IB=1,IBND	026530
ZETA = ALORNZ(IB)/(ALORNZ(IB)+ADOPP(IB))	026540
RATIO = 0.0	026550
DTEMP = 0.0	026560
IF(IB.NE.IBND) RATIO = AVOIGT(IB)/AVOIGT(IB+1)	026570
IF(IB.NE.IBND) DTEMP = ABS(TBND(IB)-TBND(IB+1))	026580
WRITE(IPR,84) IB,ZBND(IB),PBND(IB),TBND(IB),ALORNZ(IB),ADOPP(IB),	026590
1 ZETA,AVOIGT(IB),RATIO,DTEMP	026600
84 FORMAT(I5,3F10.3,2F10.5,F10.3,F10.5,F10.2,F10.1)	026610
239 CONTINUE	026620
IF(IERROR.NE.0) STOP 06	026630
C*****MERGE FASCOD1 LAYER BOUNDARIES WITH ATMOSPHERIC PROFILE LEVELS	026640
I = 0	026650
IM = 1	026660
IB = 1	026670
240 CONTINUE	026680
I = I+1	026690
IF(I.GT.IDIM) GO TO 908	026700
IF(IB.GT.IBND) GO TO 250	026710
IF(ZBND(IB).LT.ZM(IM)) GO TO 260	026720
C*****INSERT A LEVEL FROM THE ATMOSPHERIC PROFILE	026730
IF(ZBND(IB).EQ.ZM(IM)) IB = IB+1	026740
250 CONTINUE	026750
Z(I) = ZM(IM)	026760
P(I) = PM(IM)	026770
T(I) = TM(IM)	026780
RFNDX(I) = RFNDXM(IM)	026790
DO 255 K=1,KMAX	026800
DENSTY(K,I) = DENM(K,IM)	026810
255 CONTINUE	026820
IF(IM.GE.IMOD) GO TO 270	026830
IM = IM+1	026840
GO TO 240	026850
260 CONTINUE	026860
C*****INSERT A LEVEL FROM THE FASCOD1 BOUNDARIES AND INTERPOLATE	026870
C*****PRESSURE, TEMPERATURE, AND DENSITIES	026880
Z(I) = ZBND(IB)	026890
IF(IM.EQ.1) IM = 2	026900
A = (Z(I)-ZM(IM-1))/(ZM(IM)-ZM(IM-1))	026910
CALL EXPINT(P(I),PM(IM-1),PM(IM),A)	026920
T(I) = TM(IM-1)+(TM(IM)-TM(IM-1))*A	026930
CALL EXPINT(RFNDX(I),RFNDXM(IM-1),RFNDXM(IM),A)	026940
DO 265 K=1,KMAX	026950
CALL EXPINT(DENSTY(K,I),DENM(K,IM-1),DENM(K,IM),A)	026960
265 CONTINUE	026970
IB = IB+1	026980
GO TO 240	026990
270 CONTINUE	027000
IMAX = I	027010
C*****CALCULATE THE REFRACTED PATH THROUGH THE ATMOSPHERE	027020
CALL RFPATH(H1,H2,ANGLE,PHI,LEN,HMIN,IAMT:RANGE.BETA,BENDING)	027030
C*****PRINT AMOUNTS BY LAYER AND ACCUMULATE TOTALS	027040
IF(NOPRNT.NE.1) WRITE(IPR,60) (HMOLS(K),K=1,KMAX)	027050
60 FORMAT('1INTEGRATED ABSORBER AMOUNTS BY LAYER',///,	027060
1 T5,'1 LAYER BOUNDARIES',T55,'INTEGRATED AMOUNTS (MOL CM-2)',	027070
2 /,T11,'FROM',T22,'TO',T30,'AIR',T36,8(1X,A8,1X),/,	027080
4 T11,'(KM)',T21,'(KM)',(T37,8A10))	027090
I2 = IPATH-1	027100
AIRTOT = 0.0	027110
DO 280 K=1,KMAX	027120

280	AMTTOT(K) = 0.0	027130
	HMOD = AMIN1(H1,H2)	027140
	DO 290 I=1,I2	027150
	FAC = 1.0	027160
	IF(LEN.EQ.1 .AND. ZP(I+1).LE.HMOD) FAC = 2.0	027170
	AMTAIR = RHOPSM(I)*1.0E5	027180
	AIRTOT = AIRTOT+FAC*AMTAIR	027190
	DO 285 K=1,KMAX	027200
	AMTTOT(K) = AMTTOT(K)+FAC*AMTP(K,I)	027210
285	CONTINUE	027220
	IF(NOPRNT.NE.1) WRITE(IPR,61) I,ZP(I),ZP(I+1),AMTAIR,(AMTP(K,I),	027230
	1 K=1,KMAX)	027240
61	FORMAT(15,2F10.3,1P9E10.3,/, (35X,1P8E10.3))	027250
290	CONTINUE	027260
	IF(NOPRNT.NE.1) WRITE(IPR,62) H1,H2,AIRTOT,(AMTTOT(K),K=1,KMAX)	027270
62	FORMAT('TOTAL',F9.3,F10.3,1P9E10.3,/, (35X,1P8E10.3))	027280
300	CONTINUE	027290
C*****	PRINT SUMMARY OF PATH	027300
	AIRMAS = AIRTOT/AIRMS1	027310
	WRITE(IPR,63) HMOD,H1,H2,ANGLE,RANGE,BETA,PHI,HMIN,BENDNG,LEN,	027320
	1 AIRMAS	027330
63	FORMAT('1 SUMMARY OF THE GEOMETRY CALCULATION',/,	027340
1	10X,'MODEL' = ',4X,3A8,/'	027350
2	10X,'H1' = ',F10.3,' KM',/,10X,'H2' = ',F10.3,' KM',/,	027360
3	10X,'ANGLE' = ',F10.3,' DEG',/,10X,'RANGE' = ',F10.3,' KM',/,	027370
4	10X,'BETA' = ',F10.3,' DEG',/,10X,'PHI' = ',F10.3,' DEG',/,	027380
5	10X,'HMIN' = ',F10.3,' KM',/,10X,'BENDING' = ',F10.3,' DEG',/	027390
6	10X,'LEN' = ',110,/,10X,'AIRMAS' = ',G10.3,	027400
	'RELATIVE TO A VERTICAL PATH , GROUND TO SPACE')	027410
C*****	RETRIEVE THE LAYERS FROM HMIN TO MAX(H1,H2) DEFINED BY THE	027420
C*****	BOUNDARIES HMIN,H1,H2 AND ZBND	027430
	I = 1	027440
	I2 = IPATH-1	027450
	ZOUT(I) = ZP(I)	027460
C*****	FIND SMALLEST ZBND.GT.HMIN	027470
	DO 305 IB=1,IBND	027480
	IF(ZBND(IB).GT.HMIN) GO TO 310	027490
305	CONTINUE	027500
	IB = IBND	027510
310	CONTINUE	027520
	DO 360 IP=1,I2	027530
	PBAR(I) = PBAR(I)+PPSUM(IP)	027540
	TBAR(I) = TBAR(I)+TPSUM(IP)	027550
	RHOSUM(I) = RHOSUM(I)+RHOPSM(IP)	027560
	SOUT(I) = SOUT(I)+SP(IP)	027570
	DO 320 K=1,KMAX	027580
	AMOUNT(K,I) = AMOUNT(K,I)+AMTP(K,IP)	027590
320	CONTINUE	027600
	IF(ZOUT(I).EQ.HMOD) IHMOD = I	027610
	IF(IP.EQ.I2) GO TO 360	027620
C*****	TEST FOR JUMP UP TO THE NEXT LAYER OF ZOUT	027630
	IF(ZP(IP+1).EQ.ZBND(IB)) GO TO 330	027640
	IF(LEN.EQ.1 .AND. ZP(IP+1).EQ.HMOD) GO TO 340	027650
	GO TO 360	027660
C*****	JUMP TO THE NEXT LAYER OF ZBND	027670
330	IB = IB+1	027680
	IF(IB.GT.IBND) IB = IBND	027690
C*****	JUMP TO THE NEXT LAYER IN ZOUT	027700
340	I = I+1	027710
	ZOUT(I) = ZP(IP+1)	027720

360 CONTINUE	027730
IOUTMX = I+1	027740
ZOUT(IOUTMX) = ZP(IPATH)	027750
IF(ZOUT(IOUTMX).EQ.HMID) IHMID = IOUTMX	027760
C*****CALCULATE THE DENSITY WIEGHTED PRESSURE AND TEMPERATURE AND	027770
C*****ZERO OUT LAYER AMOUNTS AFTER 99.9 PERCENT OF THE TOTAL	027780
DO 405 K=1,KMAX	027790
AMTCUM(K) = 0.0	027800
ISKIP(K) = 0	027810
IF(AMTTOT(K).EQ.0.0) ISKIP(K) = 1	027820
405 CONTINUE	027830
L2 = IOUTMX-1	027840
LMAX = L2	027850
DO 450 L=1,L2	027860
PBAR(L) = PBAR(L)/RHOSUM(L)	027870
TBAR(L) = TBAR(L)/RHOSUM(L)	027880
C*****ADJUST RHOSUM FOR THE PATH LENGTH IN CM NOT KM	027890
PHOSUM(L) = RHOSUM(L)*1.0E+5	027900
C*****CALCULATE THE AMOUNT OF N2 TO DETERMINE THE PRESSURE BROADENING	027910
WN2L(L) = RHOSUM(L)*VMIXN2*1.0E-6	027920
C*****CALCULATE 'EFFECTIVE SECANT' SECNTA	027930
SECNTA(L) = SOUT(L)/(ZOUT(L+1)-ZOUT(L))	027940
ALTB(L) = ZOUT(L)	027950
ALTB(L) = ZOUT(L+1)	027960
C*****SET ICNTRL	027970
IF(LEN.EQ.1) GO TO 410	027980
IF(H1.LT.H2) ICNTRL(L) = 3	027990
IF(H1.GT.H2) ICNTRL(L) = 1	028000
GO TO 415	028010
410 CONTINUE	028020
IF(ZOUT(L).LT.HMID) ICNTRL(L) = 2	028030
IF(ZOUT(L).GE.HMID .AND. H1.GT.H2) ICNTRL(L) = 1	028040
IF(ZOUT(L).GE.HMID .AND. H1.LT.H2) ICNTRL(L) = 3	028050
415 CONTINUE	028060
C*****TEST FOR ZEROING OF AMOUNTS	028070
ISKPT = 0	028080
FAC = 1	028090
IF(ICNTRL(L).EQ.2) FAC = 2	028100
DO 440 K=1,KMAX	028110
IF(ISKIP(K).EQ.1) GO TO 420	028120
IF(NOZERO.EQ.1 .OR. K.EQ.7 .CR.	028130
1 (IEMIT.EQ.1 .AND. ICNTRL(L).NE.3)) GO TO 430	028140
IF(((AMTTOT(K)-AMTCUM(K))/AMTTOT(K)).GT.C.001) GO TO 430	028150
420 CONTINUE	028160
C*****ZERO OUT THIS AMOUNT	028170
ISKIP(K) = 1	028180
AMOUNT(K,L) = 0.0	028190
ISKPT = ISKPT+1	028200
C*****IF ALL BUT 02 ARE ZEROED, ELIMINATE ALL HIGHER LAYERS	028210
IF(ISKPT.GE.(KMAX-1)) GO TO 460	028220
430 CONTINUE	028230
AMTCUM(K) = AMTCUM(K)+FAC*AMOUNT(K,L)	028240
440 CONTINUE	028250
LMAX = L	028260
450 CONTINUE	028270
460 CONTINUE	028280
C*****OUTPUT THE PROFILE	028290
WRITE(IPR,64) (HMOLS(K),K=1,KMAX)	028300
64 FORMAT('OFINAL SET OF LAYERS FOR INPUT TO FASCOD1',/,	028310
1 ' A LAYER AMOUNT MAY BE SET TO ZERO IF THE CUMULATIVE ',	028320

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2  'AMOUNT FOR THAT LAYER AND ABOVE IS LESS THAN 0.1 PERCENT',/, 028330
3  ' OF THE TOTAL AMOUNT. THIS IS DONE ONLY FOR THE ', 028340
4  'FOLLOWING CASES',/,5X,1. IEMIT = 0 (TRANSMITTANCE)',/,5X, 028350
5  '2. IEMIT = 1 (RADIANCE) AND ICNTRL = 3 (PATH LOOKING UP)',/, 028360
6  ' O2 IS NOT INCLUDED',/, ' IF THE AMOUNTS FOR ALL THE ', 028370
7  ' MOLECULES BUT O2 ARE ZEROED, THE REMAINING LAYERS ARE ', 028380
8  'ELIMINATED',/,/,T5,L LAYER BOUNDARIES',T26,'ICNTRL',T34, 028390
9  'PBAR',T43,'TBAR',T65,'INTEGRATED AMOUNTS (MOLS CM-2)',/, 028400
*  T11,'FROM',T22,'TO',/, 028410
1  T11,'(KM)',T21,'(KM)',T34,'(MB)',T44,'(K)',T52,'AIR', 028420
2  (T57,BA9)) 028430
IF(IPUNCH.EQ.1) WRITE(IPU,65) LMAX,HMOD,H1,H2,ANGLE,LEN 028440
65 FORMAT(15,5X,3A8,' H1=',F8.2,' H2=',F8.2,' ANGLE=',F8.3, 028450
1  ' LEN=',I2) 028460
DO 470 L=1,LMAX 028470
WRITE(IPR,66) L,ZOUT(L),ZOUT(L+1),ICNTRL(L),PBAR(L),TBAR(L), 028480
1  RHOSUM(L),(AMOUNT(K,L),K=1,KMAX) 028490
66 FORMAT(/,I4,2F10.3,I4,2F9.2,1P9E9.2,/, (55X,1P8E9.2)) 028500
IF(IPUNCH.EQ.1) WRITE(IPU,68) PBAR(L),TBAR(L),ICNTRL(L), 028510
1  ZOUT(L),ZOUT(L+1) 028520
68 FORMAT(1PG10.3,OPF10.2,10X,I5,25X,F7.2,' TO',F7.2,' KM') 028530
IF(IPUNCH.NE.1) GO TO 470 028540
WRITE(IPU,70) (AMOUNT(K,L),K=1,7),WN2L(L) 028545
70 FORMAT(1P8E10.2) 028550
IF(KMAX.GT.7) WRITE(IPU,70) (AMOUNT(K,L),K=8,KMAX) 028555
470 CONTINUE 028560
NLAYRS = LMAX 028570
HT1 = HT1SLT 028580
HT2 = HT2SLT 028590
RETURN 028600
C***** 028610
C***** 028620
C*****ERROR MESSAGES 028630
C***** 028640
900 WRITE(IPR,901) MODEL,ITYPE,KMAX 028650
901 FORMAT(///,' ERROR IN INPUT, CONTROL CARD 1: ONE OF THE ', 028660
1  'PARAMETERS MODEL, ITYPE, KMAX IS OUT OF RANGE',/, 028670
2  10X,'MODEL = ',I5,/,10X,'ITYPE = ',I5,/, 028680
3  10X,'KMAX = ',I5) 028690
STOP 10 028700
902 WRITE(IPR,903) 028710
903 FORMAT(///,' ERROR: BOUNDARY ALTITUDES FOR FASCOD1 LAYERS ', 028720
1  'ARE NEGATIVE OR NOT IN ASCENDING ORDER') 028730
STOP 12 028740
904 WRITE(IPR,905) 028750
905 FORMAT('OERROR FLAG RETURNED FROM GEOINP: AN ERROR OCCURED ', 028760
1  'IN PROCESSING THE SLANT PATH PARAMETERS',/, 028770
2  'OPROGRAM STOP') 028780
STOP 14 028790
906 WRITE(IPR,907) 028800
907 FORMAT(///,' ERROR: EITHER AVTRAT.LE.1.0 OR TDIFF.LE.0',/, 028810
1  'OPROGRAM STOP') 028820
STOP 05 028830
908 WRITE(IPR,909) IDIM 028840
909 FORMAT(///,' ERROR: THE MERGING OF THE ATMOSPHERIC PROFILE ', 028850
1  'AND THE FASCODE BOUNDARIES ',/,T10,'EXCEEDS THE AVAILABLE', 028860
2  ' DIMENSION IDIM = ',I3) 028870
STOP 16 028880
END 028890

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BLOCK DATA ATMCON
C*****
C THIS SUBROUTINE INITIALIZES THE CONSTANTS USED IN THE
C PROGRAM. CONSTANTS RELATING TO THE ATMOSPHERIC PROFILES ARE STORED
C IN BLOCK DATA MLATMB.
C*****
COMMON /PARMTR/ PI,DEG,GCAIR,RE,DELTAS,ZMIN,ZMAX,IMAX,IMOD,IBMAX,
1 IOUTMX,IPATH,IMODMX,IDIM,KDIM,KMXNOM,KMAX,NOPRNT
COMMON /CONSTN/ PZERO,TZERO,AVOGAD,ALOSMT,GASCON,PLANK,BOLTZ,
1 CLIGHT,ADCON,ALZERO,AVMWT,AIRMWT,AMWT(20),VMIXST(20),VMIXN2
C& DOUBLE PRECISION HMOLS
COMMON /HMOLS/ HMOLS(20)
C*****IMODMX IS THE MAX NUMBER OF LEVELS IN THE ATMOSPHERIC PROFILE
C***** STORED IN ZM
C*****IOUTMX IS THE MAXIMUM NUMBER OF OUTPUT LAYERS
C*****IDIM IS THE MAXIMUM NUMBER OF LEVELS IN THE PROFILE Z OBTAINED
C***** BY MERGING ZM AND ZBND
C*****KDIM IS THE MAXIMUM NUMBER OF MOLECULES. KMXNOM IS THE DEFAULT
C*****IBMAX IS THE MAXIMUM NUMBER OF INPUT FASCODE LAYERS
DATA IMODMX/50/,IOUTMX/37/,IDIM/71/,KDIM/20/,KMXNOM/7/
DATA IBMAX/34/
C*****DELTAS IS THE NOMINAL SLANT PATH INCREMENT IN KM.
DATA DELTAS/5.0/
DATA PZERO/1013.25/,TZERO/273.15/
DATA AVOGAD/6.022045E+23/,ALOSMT/2.68675E+19/,
1 GASCON/8.31441E+7/,PLANK/6.626176E-27/,BOLTZ/1.380662E-16/,
2 CLIGHT/2.99792456E10/
C*****ALZERO IS THE MEAN LORENTZ HALFWIDTH AT PZERO AND 296.0 K.
C*****AVMWT IS THE MEAN MOLECULAR WEIGHT USED TO AUTOMATICALLY
C*****GENERATE THE FASCODE BOUNDARIES IN AUTLAY
DATA ALZERO/0.1/,AVMWT/36.0/
C*****ORDER OF MOLECULES H2O(1), CO2(2), O3(3), N2O(4), CO(5), CH4(6),
C***** O2(7), NO(8), SO2(9), NO2(10), NH3(11), HNO3(12), OH(13),
C***** HF(14), HCl(15), HBr(16), HI(17), ClO(18), OCS(19), H2CO(20)
DATA HMOLS/ 8H H2O , 8H CO , 8H CH4 ,
2 8H O2 , 8H NO , 8H SO2 ,
3 8H NO2 , 8H NH3 , 8H HNO3 ,
4 8H OH , 8H HF , 8H HCl ,
5 8H HBr , 8H HI , 8H ClO ,
6 8H OCS , 8H H2CO /
C*****MOLECULAR WEIGHTS
DATA AIRMWT/28.964/,AMWT/18.015,44.010,47.998,44.01,28.011,
1 16.043,31.999,30.01,64.06,46.01,17.03,63.01,17.00,20.01,
2 36.46,80.92,127.91,51.45,60.08,30.03/
C*****VMIXN2 IS THE VOLUME MIXING RATIO OF N2
DATA VMIXN2/7.8084E5/
C*****DEFAULT VOLUME MIXING RATIOS FOR THE UNIFORMLY MIXED GASES
C*****FOR USER SUPPLIED ATMOSPHERIC PROFILES,
C*****IN PARTS PER MILLION, FROM THE U. S. STANDARD ATMOSPHERE, 1976.
C*****THESE ARE NOT THE SAME VALUES AS USED IN MODELS 1 TO 6
DATA VMIXST/0.0,322., 0.0,0.27,0.19,1.5,2.0948E+5,13*0.0/
END

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BLOCK DATA MLATMB
C*****
C THIS SUBROUTINE INITIALIZES THE 6 BUILT-IN ATMOSPHERIC PROFILES
C (FROM 'OPTICAL PROPERTIES OF THE ATMOSPHERE, THIRD EDITION'
C AFCRL-72-0497 (AD 753 075) AND 'U.S. STANDARD ATMOSPHERE 1976)
C AND SETS OTHER CONSTANTS RELATED TO THE ATMOSPHERIC PROFILES
C*****
C& DOUBLE PRECISION ATMNA1,ATMNA2,ATMNA3,ATMNA4,ATMNA5,ATMNA6 C&029500
COMMON /MLATMC/ ALT(34),P1(34),P2(34),P3(34),P4(34),P5(34),P6(34) C29510
+,T1(34),T2(34),T3(34),T4(34),T5(34),T6(34) C29520
+,AMOL11(34),AMOL12(34),AMOL13(34),AMOL14(34),AMOL15(34),AMOL16(34) C29530
+,AMOL17(34),AMOL18(34) C29540
+,AMOL21(34),AMOL22(34),AMOL23(34),AMOL24(34),AMOL25(34),AMOL26(34) C29550
+,AMOL27(34),AMOL28(34) C29560
+,AMOL31(34),AMOL32(34),AMOL33(34),AMOL34(34),AMOL35(34),AMOL36(34) C29570
+,AMOL37(34),AMOL38(34) C29580
+,AMOL41(34),AMOL42(34),AMOL43(34),AMOL44(34),AMOL45(34),AMOL46(34) C29590
+,AMOL47(34),AMOL48(34) C29600
+,AMOL51(34),AMOL52(34),AMOL53(34),AMOL54(34),AMOL55(34),AMOL56(34) C29610
+,AMOL57(34),AMOL58(34) C29620
+,AMOL61(34),AMOL62(34),AMOL63(34),AMOL64(34),AMOL65(34),AMOL66(34) C29630
+,AMOL67(34),AMOL68(34) C29640
+,ATMNA1(3),ATMNA2(3),ATMNA3(3),ATMNA4(3),ATMNA5(3),ATMNA6(3) C29650
DATA ATMNA1 /8HTROPICAL,8H / C29660
DATA ATMNA2 /8HMIDLATIT,8HUDE SUMM,8HER / C29670
DATA ATMNA3 /8HMIDLATIT,8HUDE WINT,8HER / C29680
DATA ATMNA4 /8HSUBARCTI,8HC SUMMER,8H / C29690
DATA ATMNA5 /8HSUBARCTI,8HC WINTER,8H / C29700
DATA ATMNA6 /8HU. S. ST,8HANDARD,8H1962 / C29710
DATA ALT / C29720
* 0., 1., 2., 3., 4., 5., C29730
* 6., 7., 8., 9., 10., 11., C29740
* 12., 13., 14., 15., 16., 17., C29750
* 18., 19., 20., 21., 22., 23., C29760
* 24., 25., 30., 35., 40., 45., C29770
* 50., 70., 100., 0./ C29780
DATA P1 / C29790
* 1.013E+03, 9.040E+02, 8.050E+02, 7.150E+02, 6.330E+02, 5.590E+02, C29800
* 4.920E+02, 4.320E+02, 3.780E+02, 3.290E+02, 2.860E+02, 2.470E+02, C29810
* 2.130E+02, 1.820E+02, 1.560E+02, 1.320E+02, 1.110E+02, 9.370E+01, C29820
* 7.890E+01, 6.660E+01, 5.650E+01, 4.800E+01, 4.050E+01, 3.500E+01, C29830
* 3.000E+01, 2.570E+01, 1.220E+01, 6.000E+00, 3.050E+00, 1.590E+00, C29840
* 8.540E-01, 5.790E-02, 3.000E-04, 0. / C29850
DATA P2 / C29860
* 1.013E+03, 9.020E+02, 8.020E+02, 7.100E+02, 6.280E+02, 5.540E+02, C29870
* 4.870E+02, 4.260E+02, 3.720E+02, 3.240E+02, 2.810E+02, 2.430E+02, C29880
* 2.090E+02, 1.790E+02, 1.530E+02, 1.300E+02, 1.110E+02, 9.500E+01, C29890
* 8.120E+01, 6.950E+01, 5.950E+01, 5.100E+01, 4.370E+01, 3.760E+01, C29900
* 3.220E+01, 2.770E+01, 1.320E+01, 6.520E+00, 3.330E+00, 1.760E+00, C29910
* 9.510E-01, 6.710E-02, 3.000E-04, 0. / C29920
DATA P3 / C29930
* 1.018E+03, 8.973E+02, 7.897E+02, 6.938E+02, 6.081E+02, 5.313E+02, C29940
* 4.627E+02, 4.016E+02, 3.473E+02, 2.992E+02, 2.568E+02, 2.199E+02, C29950
* 1.882E+02, 1.610E+02, 1.378E+02, 1.178E+02, 1.007E+02, 8.610E+01, C29960
* 7.350E+01, 6.280E+01, 5.370E+01, 4.580E+01, 3.910E+01, 3.340E+01, C29970
* 2.860E+01, 2.430E+01, 1.110E+01, 5.180E+00, 2.530E+00, 1.240E+00, C29980
* 6.820E-01, 4.670E-02, 3.000E-04, 0. / C29990
DATA P4 / C30000
* 1.010E+03, 8.960E+02, 7.929E+02, 7.000E+02, 6.160E+02, 5.410E+02, C30010
* 4.730E+02, 4.130E+02, 3.590E+02, 3.107E+02, 2.677E+02, 2.300E+02, C30020

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* 1.977E+02,	1.700E+02,	1.460E+02,	1.250E+02,	1.080E+02,	9.28CE+01,	C30030
* 7.980E+01,	6.860E+01,	5.890E+01,	5.070E+01,	4.360E+01,	3.750E+01,	030040
* 3.227E+01,	2.780E+01,	1.340E+01,	6.610E+00,	3.400E+00,	1.810E+00,	030050
* 9.870E-01,	7.070E-02,	3.000E-04,	0.	/		030060
DATA P5 /						030070
* 1.013E+03,	8.878E+02,	7.775E+02,	6.798E+02,	5.932E+02,	5.158E+02,	030080
* 4.467E+02,	3.853E+02,	3.308E+02,	2.829E+02,	2.418E+02,	2.067E+02,	030090
* 1.766E+02,	1.510E+02,	1.291E+02,	1.103E+02,	9.431E+01,	8.058E+01,	030100
* 6.882E+01,	5.875E+01,	5.014E+01,	4.277E+01,	3.647E+01,	3.109E+01,	030110
* 2.649E+01,	2.256E+01,	1.020E+01,	4.701E+00,	2.243E+00,	1.113E+00,	030120
* 5.719E-01,	4.016E-02,	3.000E-04,	0.	/		030130
DATA P6 /						030140
* 1.013E+03,	8.986E+02,	7.950E+02,	7.012E+02,	6.166E+02,	5.405E+02,	030150
* 4.722E+02,	4.111E+02,	3.565E+02,	3.080E+02,	2.650E+02,	2.270E+02,	030160
* 1.940E+02,	1.658E+02,	1.417E+02,	1.211E+02,	1.035E+02,	8.850E+01,	030170
* 7.565E+01,	6.467E+01,	5.529E+01,	4.729E+01,	4.047E+01,	3.467E+01,	030180
* 2.972E+01,	2.549E+01,	1.197E+01,	5.746E+00,	2.871E+00,	1.491E+00,	030190
* 7.978E-01,	5.520E-02,	3.008E-04,	0.	/		030200
DATA T1 /						030210
* 3.000E+02,	2.940E+02,	2.880E+02,	2.840E+02,	2.770E+02,	2.700E+02,	030220
* 2.640E+02,	2.570E+02,	2.500E+02,	2.440E+02,	2.370E+02,	2.300E+02,	030230
* 2.240E+02,	2.170E+02,	2.100E+02,	2.040E+02,	1.970E+02,	1.950E+02,	030240
* 1.990E+02,	2.030E+02,	2.070E+02,	2.110E+02,	2.150E+02,	2.170E+02,	030250
* 2.190E+02,	2.210E+02,	2.320E+02,	2.430E+02,	2.540E+02,	2.650E+02,	030260
* 2.700E+02,	2.190E+02,	2.100E+02,	1.900E+02/			030270
DATA T2 /						030280
* 2.940E+02,	2.900E+02,	2.850E+02,	2.790E+02,	2.730E+02,	2.670E+02,	030290
* 2.610E+02,	2.550E+02,	2.480E+02,	2.420E+02,	2.350E+02,	2.290E+02,	030300
* 2.220E+02,	2.160E+02,	2.160E+02,	2.160E+02,	2.160E+02,	2.160E+02,	030310
* 2.160E+02,	2.170E+02,	2.180E+02,	2.190E+02,	2.200E+02,	2.220E+02,	030320
* 2.230E+02,	2.240E+02,	2.340E+02,	2.450E+02,	2.580E+02,	2.700E+02,	030330
* 2.760E+02,	2.180E+02,	2.100E+02,	1.900E+02/			030340
DATA T3 /						030350
* 2.722E+02,	2.687E+02,	2.652E+02,	2.617E+02,	2.557E+02,	2.497E+02,	030360
* 2.437E+02,	2.377E+02,	2.317E+02,	2.257E+02,	2.197E+02,	2.192E+02,	030370
* 2.187E+02,	2.182E+02,	2.177E+02,	2.173E+02,	2.167E+02,	2.162E+02,	030380
* 2.157E+02,	2.152E+02,	2.152E+02,	2.152E+02,	2.152E+02,	2.152E+02,	030390
* 2.152E+02,	2.152E+02,	2.174E+02,	2.278E+02,	2.432E+02,	2.585E+02,	030400
* 2.657E+02,	2.307E+02,	2.102E+02,	1.900E+02/			030410
DATA T4 /						030420
* 2.870E+02,	2.820E+02,	2.760E+02,	2.710E+02,	2.660E+02,	2.600E+02,	030430
* 2.530E+02,	2.460E+02,	2.390E+02,	2.320E+02,	2.250E+02,	2.250E+02,	030440
* 2.250E+02,	2.250E+02,	2.250E+02,	2.250E+02,	2.250E+02,	2.250E+02,	030450
* 2.250E+02,	2.250E+02,	2.250E+02,	2.250E+02,	2.250E+02,	2.250E+02,	030460
* 2.260E+02,	2.280E+02,	2.350E+02,	2.470E+02,	2.620E+02,	2.740E+02,	030470
* 2.770E+02,	2.160E+02,	2.100E+02,	1.900E+02/			030480
DATA T5 /						030490
* 2.571E+02,	2.591E+02,	2.559E+02,	2.527E+02,	2.477E+02,	2.409E+02,	030500
* 2.341E+02,	2.273E+02,	2.206E+02,	2.172E+02,	2.172E+02,	2.172E+02,	030510
* 2.172E+02,	2.172E+02,	2.172E+02,	2.172E+02,	2.166E+02,	2.160E+02,	030520
* 2.154E+02,	2.148E+02,	2.141E+02,	2.136E+02,	2.130E+02,	2.124E+02,	030530
* 2.118E+02,	2.112E+02,	2.160E+02,	2.222E+02,	2.347E+02,	2.470E+02,	030540
* 2.593E+02,	2.457E+02,	2.100E+02,	1.900E+02/			030550
DATA T6 /						030560
* 2.881E+02,	2.816E+02,	2.751E+02,	2.687E+02,	2.622E+02,	2.557E+02,	030570
* 2.492E+02,	2.427E+02,	2.362E+02,	2.297E+02,	2.232E+02,	2.168E+02,	030580
* 2.166E+02,	2.166E+02,	2.166E+02,	2.166E+02,	2.166E+02,	2.166E+02,	030590
* 2.166E+02,	2.166E+02,	2.166E+02,	2.176E+02,	2.186E+02,	2.196E+02,	030600
* 2.206E+02,	2.216E+02,	2.265E+02,	2.365E+02,	2.534E+02,	2.642E+02,	030610
* 2.706E+02,	2.197E+02,	2.100E+02,	1.900E+02/			030620

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DATA AMOL11 /
* 6.353E+17, 4.347E+17, 3.110E+17, 1.571E+17, 7.356E+16, 5.015E+16, 030630
* 2.842E+16, 1.571E+16, 6.359E+15, 4.012E+15, 1.672E+15, 5.624E+14, 030640
* 2.006E+14, 6.018E+13, 3.344E+13, 2.541E+13, 2.140E+13, 1.872E+13, 030650
* 1.672E+13, 1.638E+13, 1.505E+13, 1.705E+13, 1.705E+13, 1.806E+13, 030660
* 2.006E+13, 2.240E+13, 1.204E+13, 3.678E+12, 1.438E+12, 6.353E+11, 030670
* 2.106E+11, 4.681E+09, 3.344E+07, 0. / 030680
DATA AMOL12 /
* 7.864E+15, 7.208E+15, 6.580E+15, 5.968E+15, 5.440E+15, 4.934E+15, 030690
* 4.447E+15, 4.014E+15, 3.612E+15, 3.223E+15, 2.885E+15, 2.568E+15, 030700
* 2.273E+15, 2.005E+15, 1.776E+15, 1.547E+15, 1.347E+15, 1.149E+15, 030710
* 9.480E+14, 7.844E+14, 6.526E+14, 5.439E+14, 4.548E+14, 3.856E+14, 030720
* 3.275E+14, 2.780E+14, 1.257E+14, 5.903E+13, 2.871E+13, 1.435E+13, 030730
* 7.562E+12, 6.321E+11, 3.416E+09, 0. / 030740
DATA AMOL13 /
* 7.028E+11, 7.028E+11, 6.777E+11, 6.400E+11, 5.898E+11, 5.647E+11, 030750
* 5.396E+11, 5.145E+11, 4.894E+11, 4.894E+11, 4.894E+11, 5.145E+11, 030760
* 5.396E+11, 5.647E+11, 5.647E+11, 5.898E+11, 5.898E+11, 8.659E+11, 030770
* 1.129E+12, 1.757E+12, 2.384E+12, 3.012E+12, 3.514E+12, 4.016E+12, 030780
* 4.267E+12, 4.267E+12, 3.012E+12, 1.155E+12, 5.145E+11, 1.631E+11, 030790
* 5.396E+10, 1.079E+09, 5.396E+05, 0. / 030800
DATA AMOL14 /
* 6.672E+12, 6.116E+12, 5.583E+12, 5.063E+12, 4.615E+12, 4.186E+12, 030810
* 3.773E+12, 3.406E+12, 3.065E+12, 2.734E+12, 2.448E+12, 2.178E+12, 030820
* 1.929E+12, 1.701E+12, 1.507E+12, 1.313E+12, 1.143E+12, 9.748E+11, 030830
* 8.043E+11, 6.656E+11, 5.537E+11, 4.615E+11, 3.859E+11, 3.272E+11, 030840
* 2.779E+11, 2.359E+11, 1.067E+11, 5.009E+10, 2.436E+10, 1.217E+10, 030850
* 6.417E+09, 5.364E+08, 2.698E+06, 0. / 030860
DATA AMOL15 /
* 1.787E+12, 1.638E+12, 1.496E+12, 1.356E+12, 1.236E+12, 1.121E+12, 030870
* 1.011E+12, 9.122E+11, 8.210E+11, 7.324E+11, 6.556E+11, 5.835E+11, 030880
* 5.167E+11, 4.558E+11, 4.037E+11, 3.516E+11, 3.062E+11, 2.611E+11, 030890
* 2.154E+11, 1.783E+11, 1.483E+11, 1.236E+11, 1.034E+11, 8.764E+10, 030900
* 7.444E+10, 6.319E+10, 2.857E+10, 1.342E+10, 6.525E+09, 3.260E+09, 030910
* 1.719E+09, 1.437E+08, 7.763E+05, 0. / 030920
DATA AMOL16 /
* 3.813E+13, 3.495E+13, 3.191E+13, 2.893E+13, 2.637E+13, 2.392E+13, 030930
* 2.156E+13, 1.946E+13, 1.751E+13, 1.562E+13, 1.399E+13, 1.245E+13, 030940
* 1.102E+13, 9.723E+12, 8.612E+12, 7.501E+12, 6.532E+12, 5.570E+12, 030950
* 4.596E+12, 3.803E+12, 3.164E+12, 2.637E+12, 2.205E+12, 1.870E+12, 030960
* 1.588E+12, 1.348E+12, 6.396E+11, 2.862E+11, 1.392E+11, 6.955E+10, 030970
* 3.677E+10, 3.065E+09, 1.656E+07, 0. / 030980
DATA AMOL17 /
* 4.992E+18, 4.576E+18, 4.178E+18, 3.789E+18, 3.453E+18, 3.132E+18, 030990
* 2.823E+18, 2.548E+18, 2.293E+18, 2.046E+18, 1.831E+18, 1.630E+18, 031000
* 1.443E+18, 1.273E+18, 1.128E+18, 9.822E+17, 8.553E+17, 7.294E+17, 031010
* 6.016E+17, 4.980E+17, 4.143E+17, 3.453E+17, 2.887E+17, 2.448E+17, 031020
* 2.079E+17, 1.765E+17, 1.798E+16, 3.748E+16, 1.823E+16, 9.107E+15, 031030
* 4.801E+15, 4.013E+14, 2.168E+12, 0. / 031040
DATA AMOL18 /
* 1.861E+19, 1.706E+19, 1.557E+19, 1.412E+19, 1.287E+19, 1.167E+19, 031050
* 1.052E+19, 9.498E+18, 8.548E+18, 7.626E+18, 6.826E+18, 6.076E+18, 031060
* 5.380E+18, 4.745E+18, 4.203E+18, 3.661E+18, 3.188E+18, 2.719E+18, 031070
* 2.243E+18, 1.856E+18, 1.544E+18, 1.287E+18, 1.076E+18, 9.125E+17, 031080
* 7.750E+17, 6.579E+17, 2.975E+17, 1.397E+17, 6.794E+16, 3.395E+16, 031090
* 1.790E+16, 1.496E+15, 8.983E+12, 0. / 031100
DATA AMOL21 /
* 4.681E+17, 3.110E+17, 1.973E+17, 1.103E+17, 6.253E+16, 3.344E+16, 031110
* 2.040E+16, 1.237E+16, 7.022E+15, 4.012E+15, 2.140E+15, 7.356E+14, 031120
* 2.006E+14, 6.018E+13, 3.344E+13, 2.541E+13, 2.140E+13, 1.872E+13, 031130

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* 1.672E+13, 1.638E+13, 1.505E+13, 1.705E+13, 1.705E+13, 1.606E+13, 031230
* 2.006E+13, 2.240E+13, 1.204E+13, 3.678E+12, 1.438E+12, 6.353E+11, 031240
* 2.106E+11, 4.681E+09, 3.344E+07, 0. / 031250
DATA AMOL22 / 031260
* 8.084E+15, 7.334E+15, 6.663E+15, 6.048E+15, 5.479E+15, 4.950E+15, 031270
* 4.455E+15, 3.990E+15, 3.584E+15, 3.203E+15, 2.858E+15, 2.537E+15, 031280
* 2.251E+15, 1.981E+15, 1.694E+15, 1.439E+15, 1.223E+15, 1.052E+15, 031290
* 8.988E+14, 7.658E+14, 6.526E+14, 5.568E+14, 4.749E+14, 4.049E+14, 031300
* 3.452E+14, 2.957E+14, 1.349E+14, 6.363E+13, 3.086E+13, 1.559E+13, 031310
* 8.238E+12, 7.359E+11, 3.416E+09, 0. / 031320
DATA AMOL23 / 031330
* 7.530E+11, 7.530E+11, 7.530E+11, 7.781E+11, 8.032E+11, 8.283E+11, 031340
* 8.659E+11, 9.412E+11, 9.914E+11, 1.079E+12, 1.129E+12, 1.380E+12, 031350
* 1.506E+12, 1.882E+12, 2.259E+12, 2.384E+12, 2.635E+12, 3.012E+12, 031360
* 3.514E+12, 4.016E+12, 4.267E+12, 4.518E+12, 4.518E+12, 4.267E+12, 031370
* 4.016E+12, 3.765E+12, 2.510E+12, 1.155E+12, 5.145E+11, 1.631E+11, 031380
* 5.396E+10, 1.079E+09, 5.396E+05, 0. / 031390
DATA AMOL24 / 031400
* 6.859E+12, 6.223E+12, 5.654E+12, 5.132E+12, 4.649E+12, 4.200E+12, 031410
* 3.780E+12, 3.386E+12, 3.041E+12, 2.715E+12, 2.425E+12, 2.153E+12, 031420
* 1.910E+12, 1.681E+12, 1.437E+12, 1.221E+12, 1.043E+12, 8.922E+11, 031430
* 7.226E+11, 6.497E+11, 5.537E+11, 4.724E+11, 4.030E+11, 3.436E+11, 031440
* 2.929E+11, 2.509E+11, 1.144E+11, 5.399E+10, 2.618E+10, 1.322E+10, 031450
* 6.990E+09, 6.244E+08, 2.898E+06, 0. / 031460
DATA AMOL25 / 031470
* 1.837E+12, 1.667E+12, 1.514E+12, 1.375E+12, 1.245E+12, 1.125E+12, 031480
* 1.012E+12, 9.069E+11, 8.146E+11, 7.272E+11, 6.496E+11, 5.766E+11, 031490
* 5.116E+11, 4.503E+11, 3.849E+11, 3.270E+11, 2.792E+11, 2.390E+11, 031500
* 2.043E+11, 1.740E+11, 1.483E+11, 1.265E+11, 1.079E+11, 9.203E+10, 031510
* 7.846E+10, 6.720E+10, 3.065E+10, 1.446E+10, 7.014E+09, 3.542E+09, 031520
* 1.872E+09, 1.673E+08, 7.763E+05, 0. / 031530
DATA AMOL26 / 031540
* 3.919E+13, 3.556E+13, 3.231E+13, 2.932E+13, 2.657E+13, 2.400E+13, 031550
* 2.160E+13, 1.935E+13, 1.738E+13, 1.551E+13, 1.386E+13, 1.230E+13, 031560
* 1.091E+13, 9.607E+12, 8.211E+12, 6.977E+12, 5.957E+12, 5.099E+12, 031570
* 4.358E+12, 3.713E+12, 3.164E+12, 2.700E+12, 2.303E+12, 1.963E+12, 031580
* 1.674E+12, 1.434E+12, 6.539E+11, 3.085E+11, 1.496E+11, 7.557E+10, 031590
* 3.994E+10, 3.568E+09, 1.656E+07, 0. / 031600
DATA AMOL27 / 031610
* 5.132E+18, 4.656E+18, 4.230E+18, 3.840E+18, 3.478E+18, 3.142E+18, 031620
* 2.828E+18, 2.533E+18, 2.275E+18, 2.031E+18, 1.815E+18, 1.611E+18, 031630
* 1.420E+18, 1.258E+18, 1.075E+18, 9.135E+17, 7.800E+17, 6.676E+17, 031640
* 5.706E+17, 4.861E+17, 4.143E+17, 3.535E+17, 3.015E+17, 2.571E+17, 031650
* 2.192E+17, 1.877E+17, 8.562E+16, 4.039E+16, 1.959E+16, 9.894E+15, 031660
* 5.230E+15, 4.672E+14, 2.169E+12, 0. / 031670
DATA AMOL28 / 031680
* 1.913E+19, 1.706E+19, 1.577E+19, 1.431E+19, 1.297E+19, 1.171E+19, 031690
* 1.054E+19, 9.442E+18, 8.481E+18, 7.572E+18, 6.764E+18, 6.003E+18, 031700
* 5.326E+18, 4.689E+18, 4.008E+18, 3.405E+18, 2.908E+18, 2.489E+18, 031710
* 2.127E+18, 1.812E+18, 1.544E+18, 1.318E+18, 1.124E+18, 9.583E+17, 031720
* 8.170E+17, 6.996E+17, 3.192E+17, 1.506E+17, 7.302E+16, 3.688E+16, 031730
* 1.949E+16, 1.741E+15, 8.083E+12, 0. / 031740
DATA AMOL31 / 031750
* 1.170E+17, 8.359E+15, 6.018E+16, 4.012E+16, 2.207E+16, 1.271E+16, 031760
* 7.022E+15, 2.842E+15, 1.170E+15, 5.350E+14, 2.508E+14, 2.307E+14, 031770
* 2.006E+14, 6.018E+13, 3.344E+13, 2.541E+13, 2.140E+13, 1.872E+13, 031780
* 1.672E+13, 1.638E+13, 1.505E+13, 1.705E+13, 1.705E+13, 1.606E+13, 031790
* 2.006E+13, 2.240E+13, 1.204E+13, 3.678E+12, 1.438E+12, 6.353E+11, 031800
* 2.106E+11, 4.681E+09, 3.344E+07, 0. / 031810
DATA AMOL32 / 031820

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* 8.903E+15,	7.957E+15,	7.100E+15,	6.326E+15,	5.679E+15,	5.083E+15,	031830
* 4.537E+15,	4.039E+15,	3.583E+15,	3.169E+15,	2.795E+15,	2.399E+15,	031840
* 2.057E+15,	1.764E+15,	1.513E+15,	1.297E+15,	1.111E+15,	9.522E+14,	031850
* 8.147E+14,	6.977E+14,	5.966E+14,	5.089E+14,	4.344E+14,	3.711E+14,	031860
* 3.178E+14,	2.700E+14,	1.221E+14,	5.437E+13,	2.487E+13,	1.193E+13,	031870
* 6.137E+12,	4.840E+11,	3.412E+09,	0.	/		031880
DATA AMOL33 /						031890
* 7.530E+11,	6.777E+11,	6.149E+11,	6.149E+11,	6.149E+11,	7.279E+11,	031900
* 8.032E+11,	9.663E+11,	1.129E+12,	1.506E+12,	2.008E+12,	2.635E+12,	031910
* 3.263E+12,	3.765E+12,	4.016E+12,	4.267E+12,	4.518E+12,	4.894E+12,	031920
* 5.145E+12,	5.396E+12,	5.647E+12,	5.396E+12,	5.396E+12,	4.894E+12,	031930
* 4.518E+12,	4.267E+12,	2.384E+12,	1.155E+12,	5.145E+11,	1.631E+11,	031940
* 5.396E+10,	1.079E+09,	5.396E+05,	0.	/		031950
DATA AMOL34 /						031960
* 7.554E+12,	6.751E+12,	6.024E+12,	5.367E+12,	4.818E+12,	4.313E+12,	031970
* 3.850E+12,	3.427E+12,	3.041E+12,	2.689E+12,	2.371E+12,	2.035E+12,	031980
* 1.746E+12,	1.497E+12,	1.284E+12,	1.100E+12,	9.427E+11,	8.079E+11,	031990
* 6.913E+11,	5.920E+11,	5.062E+11,	4.318E+11,	3.686E+11,	3.149E+11,	032000
* 2.696E+11,	2.291E+11,	1.036E+11,	4.613E+10,	2.110E+10,	1.012E+10,	032010
* 5.207E+09,	4.107E+08,	2.895E+06,	0.	/		032020
DATA AMOL35 /						032030
* 2.023E+12,	1.808E+12,	1.614E+12,	1.438E+12,	1.291E+12,	1.155E+12,	032040
* 1.031E+12,	9.179E+11,	8.144E+11,	7.203E+11,	6.351E+11,	5.451E+11,	032050
* 4.676E+11,	4.009E+11,	3.440E+11,	2.947E+11,	2.525E+11,	2.164E+11,	032060
* 1.852E+11,	1.586E+11,	1.356E+11,	1.156E+11,	9.873E+10,	8.434E+10,	032070
* 7.222E+10,	6.136E+10,	2.774E+10,	1.236E+10,	5.653E+09,	2.712E+09,	032080
* 1.395E+09,	1.100E+08,	7.755E+05,	0.	/		032090
DATA AMOL36 /						032100
* 4.317E+13,	3.858E+13,	3.442E+13,	3.067E+13,	2.753E+13,	2.465E+13,	032110
* 2.200E+13,	1.958E+13,	1.737E+13,	1.537E+13,	1.355E+13,	1.163E+13,	032120
* 9.976E+12,	8.554E+12,	7.338E+12,	6.287E+12,	5.387E+12,	4.617E+12,	032130
* 3.950E+12,	3.383E+12,	2.893E+12,	2.467E+12,	2.106E+12,	1.799E+12,	032140
* 1.541E+12,	1.309E+12,	5.919E+11,	2.636E+11,	1.206E+11,	5.785E+10,	032150
* 2.976E+10,	2.347E+09,	1.654E+07,	0.	/		032160
DATA AMOL37 /						032170
* 5.652E+18,	5.051E+18,	4.507E+18,	4.016E+18,	3.605E+18,	3.227E+18,	032180
* 2.880E+18,	2.564E+18,	2.275E+18,	2.012E+18,	1.774E+18,	1.523E+18,	032190
* 1.306E+18,	1.120E+18,	9.608E+17,	8.232E+17,	7.054E+17,	6.045E+17,	032200
* 5.172E+17,	4.430E+17,	3.788E+17,	3.230E+17,	2.758E+17,	2.356E+17,	032210
* 2.017E+17,	1.714E+17,	7.750E+16,	3.451E+16,	1.579E+16,	7.575E+15,	032220
* 3.896E+15,	3.073E+14,	2.166E+12,	0.	/		032230
DATA AMOL38 /						032240
* 2.107E+19,	1.883E+19,	1.680E+19,	1.497E+19,	1.344E+19,	1.203E+19,	032250
* 1.074E+19,	9.557E+18,	8.480E+18,	7.500E+18,	6.613E+18,	5.676E+18,	032260
* 4.869E+18,	4.175E+18,	3.581E+18,	3.069E+18,	2.629E+18,	2.253E+18,	032270
* 1.928E+18,	1.651E+18,	1.412E+18,	1.204E+18,	1.028E+18,	8.781E+17,	032280
* 7.519E+17,	6.389E+17,	2.889E+17,	1.287E+17,	5.886E+16,	2.823E+16,	032290
* 1.452E+16,	1.145E+15,	8.075E+12,	0.	/		032300
DATA AMOL41 /						032310
* 3.043E+17,	2.006E+17,	1.404E+17,	9.028E+16,	5.684E+16,	3.344E+16,	032320
* 1.806E+16,	9.696E+15,	4.347E+15,	1.404E+15,	5.015E+14,	3.143E+14,	032330
* 2.006E+14,	6.018E+13,	3.344E+13,	2.541E+13,	2.140E+13,	1.872E+13,	032340
* 1.672E+13,	1.638E+13,	1.505E+13,	1.705E+13,	1.705E+13,	1.806E+13,	032350
* 2.006E+13,	2.240E+13,	1.204E+13,	3.678E+12,	1.438E+12,	6.353E+11,	032360
* 2.106E+11,	4.681E+09,	3.344E+07,	0.	/		032370
DATA AMOL42 /						032380
* 8.314E+15,	7.531E+15,	6.822E+15,	6.146E+15,	5.518E+15,	4.964E+15,	032390
* 4.464E+15,	4.011E+15,	3.590E+15,	3.202E+15,	2.845E+15,	2.444E+15,	032400
* 2.101E+15,	1.806E+15,	1.551E+15,	1.328E+15,	1.148E+15,	9.861E+14,	032410
* 8.480E+14,	7.290E+14,	6.259E+14,	5.388E+14,	4.633E+14,	3.985E+14,	032420

* 3.414E+14,	2.915E+14,	1.363E+14,	6.398E+13,	3.103E+13,	1.579E+13,	032430
* 8.519E+12,	7.826E+11,	3.416E+09,	0.	/		032440
DATA AMOL43 /						032450
* 6.149E+11,	6.777E+11,	7.028E+11,	7.279E+11,	7.530E+11,	8.032E+11,	032460
* 8.910E+11,	9.412E+11,	9.914E+11,	1.380E+12,	1.631E+12,	2.259E+12,	032470
* 2.635E+12,	3.263E+12,	3.514E+12,	4.016E+12,	4.267E+12,	4.894E+12,	032480
* 5.145E+12,	5.145E+12,	4.894E+12,	4.518E+12,	4.016E+12,	3.765E+12,	032490
* 3.514E+12,	3.263E+12,	1.757E+12,	1.155E+12,	5.145E+11,	1.631E+11,	032500
* 5.396E+10,	1.079E+09,	5.396E+05,	0.	/		032510
DATA AMOL44 /						032520
* 7.054E+12,	6.390E+12,	5.789E+12,	5.215E+12,	4.682E+12,	4.212E+12,	032530
* 3.788E+12,	3.403E+12,	3.046E+12,	2.716E+12,	2.414E+12,	2.074E+12,	032540
* 1.782E+12,	1.533E+12,	1.316E+12,	1.127E+12,	9.738E+11,	8.367E+11,	032550
* 7.195E+11,	6.185E+11,	5.311E+11,	4.571E+11,	3.931E+11,	3.381E+11,	032560
* 2.897E+11,	2.474E+11,	1.157E+11,	5.429E+10,	2.633E+10,	1.340E+10,	032570
* 7.229E+09,	6.640E+08,	2.898E+06,	0.	/		032580
DATA AMOL45 /						032590
* 1.889E+12,	1.712E+12,	1.551E+12,	1.397E+12,	1.254E+12,	1.128E+12,	032600
* 1.015E+12,	9.116E+11,	8.159E+11,	7.276E+11,	6.465E+11,	5.555E+11,	032610
* 4.775E+11,	4.106E+11,	3.526E+11,	3.019E+11,	2.608E+11,	2.241E+11,	032620
* 1.927E+11,	1.657E+11,	1.422E+11,	1.224E+11,	1.053E+11,	9.057E+10,	032630
* 7.759E+10,	6.625E+10,	3.098E+10,	1.454E+10,	7.052E+09,	3.590E+09,	032640
* 1.936E+09,	1.779E+08,	7.763E+05,	0.	/		032650
DATA AMOL46 /						032660
* 4.031E+13,	3.651E+13,	3.308E+13,	2.980E+13,	2.675E+13,	2.407E+13,	032670
* 2.164E+13,	1.945E+13,	1.741E+13,	1.552E+13,	1.379E+13,	1.185E+13,	032680
* 1.019E+13,	8.759E+12,	7.522E+12,	6.440E+12,	5.564E+12,	4.781E+12,	032690
* 4.111E+12,	3.534E+12,	3.035E+12,	2.612E+12,	2.246E+12,	1.932E+12,	032700
* 1.655E+12,	1.413E+12,	6.610E+11,	3.102E+11,	1.504E+11,	7.658E+10,	032710
* 4.131E+10,	3.794E+09,	1.656E+07,	0.	/		032720
DATA AMOL47 /						032730
* 5.278E+18,	4.781E+18,	4.331E+18,	3.902E+18,	3.503E+18,	3.151E+18,	032740
* 2.834E+18,	2.546E+18,	2.279E+18,	2.033E+18,	1.806E+18,	1.552E+18,	032750
* 1.334E+18,	1.147E+18,	9.849E+17,	8.433E+17,	7.286E+17,	6.260E+17,	032760
* 5.383E+17,	4.628E+17,	3.973E+17,	3.420E+17,	2.941E+17,	2.530E+17,	032770
* 2.167E+17,	1.851E+17,	8.655E+16,	4.062E+16,	1.970E+16,	1.003E+16,	032780
* 5.408E+15,	4.968E+14,	2.168E+12,	0.	/		032790
DATA AMOL48 /						032800
* 1.967E+19,	1.782E+19,	1.614E+19,	1.454E+19,	1.306E+19,	1.175E+19,	032810
* 1.056E+19,	9.491E+18,	8.495E+18,	7.576E+18,	6.731E+18,	5.783E+18,	032820
* 4.971E+18,	4.275E+18,	3.671E+18,	3.143E+18,	2.716E+18,	2.334E+18,	032830
* 2.007E+18,	1.725E+18,	1.481E+18,	1.275E+18,	1.096E+18,	9.430E+17,	032840
* 8.079E+17,	6.898E+17,	3.226E+17,	1.514E+17,	7.342E+16,	3.737E+16,	032850
* 2.016E+16,	1.852E+15,	8.083E+12,	0.	/		032860
DATA AMOL51 /						032870
* 4.012E+16,	4.012E+16,	3.143E+16,	2.274E+16,	1.371E+16,	6.687E+15,	032880
* 3.277E+15,	1.806E+15,	3.678E+14,	2.809E+14,	1.839E+14,	1.271E+14,	032890
* 8.693E+13,	6.018E+13,	3.344E+13,	2.541E+13,	2.140E+13,	1.872E+13,	032900
* 1.672E+13,	1.638E+13,	1.505E+13,	1.705E+13,	1.705E+13,	1.806E+13,	032910
* 2.006E+13,	2.240E+13,	1.204E+13,	3.678E+12,	1.438E+12,	6.353E+11,	032920
* 2.106E+11,	4.681E+09,	3.344E+07,	0.	/		032930
DATA AMOL52 /						032940
* 9.407E+15,	8.179E+15,	7.254E+15,	6.425E+15,	5.721E+15,	5.117E+15,	032950
* 4.561E+15,	4.052E+15,	3.585E+15,	3.114E+15,	2.662E+15,	2.275E+15,	032960
* 1.944E+15,	1.662E+15,	1.421E+15,	1.214E+15,	1.041E+15,	8.920E+14,	032970
* 7.639E+14,	6.539E+14,	5.599E+14,	4.787E+14,	4.094E+14,	3.500E+14,	032980
* 2.990E+14,	2.554E+14,	1.129E+14,	5.058E+13,	2.285E+13,	1.077E+13,	032990
* 5.273E+12,	3.908E+11,	3.416E+09,	0.	/		033000
DATA AMOL53 /						033010
* 5.145E+11,	5.145E+11,	5.145E+11,	5.396E+11,	5.647E+11,	5.898E+11,	033020

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* 6.149E+11, 8.910E+11, 1.129E+12, 2.006E+12, 3.012E+12, 4.016E+12, 033030
* 5.396E+12, 5.898E+12, 6.149E+12, 7.028E+12, 7.781E+12, 7.781E+12, 033040
* 7.781E+12, 7.530E+12, 7.028E+12, 6.400E+12, 5.898E+12, 5.396E+12, 033050
* 4.518E+12, 4.016E+12, 1.882E+12, 1.155E+12, 5.145E+11, 1.631E+11, 033060
* 5.396E+10, 1.079E+09, 5.396E+05, 0. / 033070
DATA AMOL54 / 033080
* 7.982E+12, 6.940E+12, 6.155E+12, 5.451E+12, 4.855E+12, 4.342E+12, 033090
* 3.870E+12, 3.438E+12, 3.042E+12, 2.642E+12, 2.258E+12, 1.931E+12, 033100
* 1.649E+12, 1.410E+12, 1.206E+12, 1.030E+12, 8.833E+11, 7.568E+11, 033110
* 6.482E+11, 5.549E+11, 4.751E+11, 4.062E+11, 3.473E+11, 2.969E+11, 033120
* 2.537E+11, 2.167E+11, 9.580E+10, 4.292E+10, 1.939E+10, 9.141E+09, 033130
* 4.474E+09, 3.316E+08, 2.898E+06, 0. / 033140
DATA AMOL55 / 033150
* 2.138E+12, 1.859E+12, 1.649E+12, 1.460E+12, 1.300E+12, 1.163E+12, 033160
* 1.037E+12, 9.210E+11, 8.148E+11, 7.078E+11, 6.049E+11, 5.171E+11, 033170
* 4.418E+11, 3.778E+11, 3.230E+11, 2.760E+11, 2.366E+11, 2.027E+11, 033180
* 1.736E+11, 1.486E+11, 1.273E+11, 1.088E+11, 9.304E+10, 7.954E+10, 033190
* 6.796E+10, 5.804E+10, 2.566E+10, 1.150E+10, 5.193E+09, 2.449E+09, 033200
* 1.198E+09, 8.882E+07, 7.763E+05, 0. / 033210
DATA AMOL56 / 033220
* 4.561E+13, 3.966E+13, 3.517E+13, 3.115E+13, 2.774E+13, 2.481E+13, 033230
* 2.212E+13, 1.965E+13, 1.738E+13, 1.510E+13, 1.291E+13, 1.103E+13, 033240
* 9.425E+12, 8.059E+12, 6.890E+12, 5.887E+12, 5.047E+12, 4.325E+12, 033250
* 3.704E+12, 3.171E+12, 2.715E+12, 2.321E+12, 1.985E+12, 1.697E+12, 033260
* 1.450E+12, 1.238E+12, 5.474E+11, 2.453E+11, 1.108E+11, 5.224E+10, 033270
* 2.557E+10, 1.895E+09, 1.656E+07, 0. / 033280
DATA AMOL57 / 033290
* 5.972E+18, 5.193E+18, 4.065E+18, 4.079E+18, 3.632E+18, 3.249E+18, 033300
* 2.896E+18, 2.573E+18, 2.276E+18, 1.977E+18, 1.690E+18, 1.444E+18, 033310
* 1.234E+18, 1.055E+18, 9.022E+17, 7.708E+17, 6.609E+17, 5.663E+17, 033320
* 4.850E+17, 4.152E+17, 3.555E+17, 3.039E+17, 2.599E+17, 2.222E+17, 033330
* 1.898E+17, 1.621E+17, 7.168E+16, 3.211E+16, 1.451E+16, 6.840E+15, 033340
* 3.348E+15, 2.481E+14, 2.168E+12, 0. / 033350
DATA AMOL58 / 033360
* 2.226E+19, 1.936E+19, 1.717E+19, 1.520E+19, 1.354E+19, 1.211E+19, 033370
* 1.079E+19, 9.589E+18, 8.484E+18, 7.369E+18, 6.299E+18, 5.384E+18, 033380
* 4.600E+18, 3.933E+18, 3.363E+18, 2.873E+18, 2.463E+18, 2.111E+18, 033390
* 1.808E+18, 1.547E+18, 1.325E+18, 1.133E+18, 9.687E+17, 8.282E+17, 033400
* 7.076E+17, 6.043E+17, 2.672E+17, 1.197E+17, 5.407E+16, 2.549E+16, 033410
* 1.248E+16, 9.248E+14, 8.083E+12, 0. / 033420
DATA AMOL61 / 033430
* 1.973E+17, 1.404E+17, 9.696E+16, 6.018E+16, 3.678E+16, 2.140E+16, 033440
* 1.271E+16, 7.022E+15, 4.012E+15, 1.538E+15, 6.018E+14, 2.742E+14, 033450
* 1.237E+14, 6.018E+13, 2.809E+13, 2.407E+13, 2.040E+13, 1.739E+13, 033460
* 1.471E+13, 1.471E+13, 1.471E+13, 1.605E+13, 1.739E+13, 1.906E+13, 033470
* 2.040E+13, 2.207E+13, 1.271E+13, 5.350E+12, 2.240E+12, 1.070E+12, 033480
* 4.012E+11, 5.015E+09, 3.344E+07, 0. / 033490
DATA AMOL62 / 033500
* 8.342E+15, 7.583E+15, 6.878E+15, 6.220E+15, 5.611E+15, 5.047E+15, 033510
* 4.526E+15, 4.048E+15, 3.607E+15, 3.205E+15, 2.839E+15, 2.503E+15, 033520
* 2.141E+15, 1.830E+15, 1.564E+15, 1.337E+15, 1.142E+15, 9.769E+14, 033530
* 8.351E+14, 7.139E+14, 6.103E+14, 5.196E+14, 4.426E+14, 3.775E+14, 033540
* 3.221E+14, 2.750E+14, 1.264E+14, 5.809E+13, 2.709E+13, 1.349E+13, 033550
* 7.049E+12, 6.007E+11, 3.425E+09, 0. / 033560
DATA AMOL63 / 033570
* 6.777E+11, 6.777E+11, 6.777E+11, 6.275E+11, 5.773E+11, 5.773E+11, 033580
* 5.647E+11, 6.149E+11, 6.526E+11, 8.910E+11, 1.129E+12, 1.631E+12, 033590
* 2.008E+12, 2.133E+12, 2.384E+12, 2.635E+12, 3.012E+12, 3.514E+12, 033600
* 4.016E+12, 4.392E+12, 4.769E+12, 4.769E+12, 4.994E+12, 4.769E+12, 033610
* 4.518E+12, 4.267E+12, 2.510E+12, 1.380E+12, 6.149E+11, 2.133E+11, 033620

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* 5.020E+10, 1.079E+09, 5.396E+05, 0. / 033630
DATA AMOL64 / 033640
* 7.078E+12, 6.434E+12, 5.836E+12, 5.277E+12, 4.760E+12, 4.282E+12, 033650
* 3.841E+12, 3.434E+12, 3.061E+12, 2.720E+12, 2.408E+12, 2.124E+12, 033660
* 1.87E+12, 1.553E+12, 1.327E+12, 1.134E+12, 9.694E+11, 8.289E+11, 033670
* 7.085E+11, 6.057E+11, 5.178E+11, 4.409E+11, 3.756E+11, 3.203E+11, 033680
* 2.733E+11, 2.333E+11, 1.072E+11, 4.929E+10, 2.298E+10, 1.145E+10, 033690
* 5.981E+09, 5.097E+08, 2.906E+06, 0. / 033700
DATA AMOL65 / 033710
* 1.896E+12, 1.723E+12, 1.563E+12, 1.414E+12, 1.275E+12, 1.147E+12, 033720
* 1.029E+12, 9.199E+11, 8.199E+11, 7.285E+11, 6.451E+11, 5.689E+11, 033730
* 4.867E+11, 4.160E+11, 3.555E+11, 3.038E+11, 2.597E+11, 2.220E+11, 033740
* 1.898E+11, 1.622E+11, 1.387E+11, 1.181E+11, 1.006E+11, 8.579E+10, 033750
* 7.321E+10, 6.250E+10, 2.872E+10, 1.320E+10, 6.156E+09, 3.067E+09, 033760
* 1.602E+09, 1.365E+08, 7.784E+05, 0. / 033770
DATA AMOL66 / 033780
* 4.045E+13, 3.677E+13, 3.335E+13, 3.016E+13, 2.720E+13, 2.447E+13, 033790
* 2.195E+13, 1.962E+13, 1.749E+13, 1.554E+13, 1.376E+13, 1.214E+13, 033800
* 1.038E+13, 8.874E+12, 7.584E+12, 6.481E+12, 5.539E+12, 4.737E+12, 033810
* 4.049E+12, 3.461E+12, 2.959E+12, 2.519E+12, 2.146E+12, 1.830E+12, 033820
* 1.562E+12, 1.333E+12, 6.126E+11, 2.816E+11, 1.313E+11, 6.542E+10, 033830
* 3.418E+10, 2.913E+09, 1.660E+07, 0. / 033840
DATA AMOL67 / 033850
* 5.296E+18, 4.814E+18, 4.366E+18, 3.949E+18, 3.562E+18, 3.204E+18, 033860
* 2.874E+18, 2.570E+18, 2.290E+18, 2.035E+18, 1.802E+18, 1.589E+18, 033870
* 1.359E+18, 1.162E+18, 9.930E+17, 8.486E+17, 7.253E+17, 6.202E+17, 033880
* 5.301E+17, 4.532E+17, 3.875E+17, 3.299E+17, 2.810E+17, 2.396E+17, 033890
* 2.045E+17, 1.746E+17, 8.021E+16, 3.686E+16, 1.720E+16, 8.566E+15, 033900
* 4.475E+15, 3.814E+14, 2.174E+12, 0. / 033910
DATA AMOL68 / 033920
* 1.974E+19, 1.794E+19, 1.627E+19, 1.472E+19, 1.328E+19, 1.194E+19, 033930
* 1.071E+19, 9.578E+18, 8.536E+18, 7.585E+18, 6.717E+18, 5.924E+18, 033940
* 5.067E+18, 4.331E+18, 3.701E+18, 3.163E+18, 2.704E+18, 2.312E+18, 033950
* 1.976E+18, 1.689E+18, 1.444E+18, 1.230E+18, 1.047E+18, 8.932E+17, 033960
* 7.622E+17, 6.508E+17, 2.990E+17, 1.375E+17, 6.410E+16, 3.193E+16, 033970
* 1.658E+16, 1.422E+15, 8.104E+12, 0. / 033980
END 033990

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SUBROUTINE MLATM(M)	034000
C*****	034010
C , THIS SUBROUTINE LOADS ONE OF THE 6 BUILT IN ATMOSPHERIC PROFILES	034020
C OR CALLS NSMDL TO READ IN A USER SUPPLIED PROFILE.	034030
C*****	034040
COMMON /IFIL/ IRD,IPR,IPU	034050
COMMON /PARMTR/ PI,DEG,GCAIR,RE,DELTAS,ZMIN,ZMAX,IMAX,IMOD,IBMAX,	034060
1 IOUTMX,IPATH,IMODMX,IDIM,KDIM,KMXNOM,KMAX,NOPRNT	034070
C& DOUBLE PRECISION HMOD	C&034080
COMMON HMOD(3),ZM(50),PM(50),TM(50),RFNDXM(50),DENM(20,50)	034090
COMMON ZP(71),PP(71),YP(71),RFNDXP(71),SP(71),	034100
1 PPSUM(71),TPSUM(71),RHOPSM(71),DENP(20,71),AMTP(20,71)	034110
COMMON Z(71),P(71),T(71),RFNDX(71),DENSTY(20,71)	034120
C& DOUBLE PRECISION ATMNAM	C&034130
COMMON /MLATMC/ ALT(34),PMDL(34,6),TMDL(34,6),AMOL(34,8,6),	034140
1 ATMNAM(3,6)	034150
IF(M.EQ.7) GO TO 200	034160
IF(M.GE.1 .OR. M.LE.6) IMOD = 33	034170
DO 100 I=1,IMOD	034180
ZM(I) = ALT(I)	034190
PM(I) = PMDL(I,M)	034200
TM(I) = TMDL(I,M)	034210
C*****AMOL(I,8,M) IS N2 AND IS NO LONGER USED	034220
DO 100 K=1,7	034230
DENM(K,I) = AMOL(I,K,M)	034240
100 CONTINUE	034250
DO 110 L=1,3	034260
110 HMOD(L) = ATMNAM(L,M)	034270
GO TO 210	034280
200 CONTINUE	034290
CALL NSMDL	034300
210 CONTINUE	034310
ZMIN = ZM(1)	034320
ZMAX = ZM(IMOD)	034330
RETURN	034340
END	034350


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1      8H      TD , 8H      RH , 8H      PPH2O , 8H      DENH2O , 034960
2      8H AMSMIX / 034970
DATA HD2/ 8H      , 8H      (KM) , 8H      (MB) , 8H      (K) , 034980
1      8H      ,(C) , 8H(PERCNT) , 8H      (MB) , 8H(GM M-3) , 034990
2      8H(GM/KG) / 035000
WRITE(IPR,20) 035010
20 FORMAT(///,' READING IN USER SUPPLIED MODEL ATMOSPHERE') 035020
READ(IRD,21) IMOD 035030
21 FORMAT(I5) 035040
READ(IRD,22) HMOD 035050
22 FORMAT(3A8) 035060
WRITE(IPR,24) IMOD, HMOD 035070
24 FORMAT(//,10X,'IMOD = ',I5,/,10X,'PROFILE = ',3A8) 035080
IF(IMOD.GT.IMODMX) GO TO 900 035090
WRITE(IPR,26) HD1,HD2 035100
26 FORMAT(/,(3X,9(1X,A8,1X))) 035110
WRITE(IPR,28) HMOLS 035120
28 FORMAT(/,' VOL MIX RAT' ,8(1X,A8,1X),/, ' (PPMV)', 035130
1 (T14,8A10)) 035140
DO 110 IM=1,IMOD 035150
READ(IRD,30) ZM(IM),PM(IM),TM(IM),TD,RH,PPH2O,DENH2O,AMSMIX 035160
30 FORMAT(8F10.3) 035170
WRITE(IPR,32) IM,ZM(IM),PM(IM),TM(IM),TD,RH,PPH2O,DENH2O,AMSMIX 035180
32 FORMAT(/,I11,8F10.3) 035190
READ(IRD,34) (VMIX(K),K=1,KMAX) 035200
34 FORMAT(8E10.3) 035210
WRITE(IPR,36) (VMIX(K),K=1,KMAX) 035220
36 FORMAT(/,11X,1P8E10.3) 035230
RHOAIR = ALQSMT*(PM(IM)/PZERO)*(TZERO/TM(IM)) 035240
DENM(1,IM) = 0.0 035250
IF(VMIX(1).GT.0.0) DENM(1,IM) = VMIX(1)*RHOAIR*1.0E-6 035260
IF(VMIX(1).EQ.0.0) CALL WATVAP(PM(IM),TM(IM),TD,RH,PPH2O, 035270
1 DENH2O,AMSMIX,DENM(1,IM)) 035280
DO 100 K=2,KMAX 035290
DENM(K,IM) = 0.0 035300
IF(VMIX(K).GT.0.0) DENM(K,IM) = VMIX(K)*RHOAIR*1.0E-6 035310
IF(VMIX(K).EQ.0.0) DENM(K,IM) = VMIXST(K)*RHOAIR*1.0E-6 035320
100 CONTINUE 035330
110 CONTINUE 035340
RETURN 035350
900 CONTINUE 035360
WRITE(IPR,902) IMOD,IMODMX 035370
902 FORMAT(/,' NUMBER OF PROFILE LEVELS IMOD = ',I5,' EXCEEDS THE ', 035380
1 'MAXIMUM ALLOWED = ',I5) 035390
END 035400

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SUBROUTINE WATVAP(P,T,TD,RH,PPH20,DENH20,AMSMIX,DENNUM) 035410
C***** 035420
C THIS SUBROUTINE COMPUTES THE WATERVAPOR NUMBER DENSITY (MOL CM-3) 035430
C GIVEN : TD = DEW POINT TEMPERATURE (DEG C), RH = RELATIVE HUMIDITY 035440
C (PERCENT), PPH20 = WATER VAPOR PARTIAL PRESSURE (MB), DENH20 = 035450
C WATER VAPOR MASS DENSITY (GM M-3), AMSMIX = MASS MIXING RATIO 035460
C (GM/KG). 035470
C IF MORE THAN ONE OF THESE QUANTITIES IS GIVEN, THE LAST ONE 035480
C GIVEN IS USED. THE FUNCTION DENSAT FOR THE SATURATION 035490
C WATER VAPOR DENSITY OVER WATER IS ACCURATE TO BETTER THAN 1 035500
C PERCENT FROM -50 TO +50 DEG C. (SEE THE LOWTRAN3 OR 5 REPORT) 035510
C***** 035520
COMMON /IFIL/ IRD,IPR,IPU 035530
COMMON /PARMTR/ PI,DEG,GCAIR,RE,DELTAS,ZMIN,ZMAX,IMAX,IMOD,IBMAX, 035540
1 IOUTMX,IPATH,IMODMX,IDIM,KDIM,KMXNOM,KMAX,NOPRNT 035550
COMMON /CONSTN/ PZERO,TZERO,AVOGAD,AOSMT,GASCON,PLANK,BOLTZ, 035560
1 CLIGHT,ADCON,ALZERO,AVMWT,AIRMWT,AMWT(20),VMIXST(20),VMIXN2 035570
DATA C1/18.9766/,C2/-14.9595/,C3/-2.4388/ 035580
DENSAT(ATEMP) = ATEMP*B*EXP(C1+C2*ATEMP+C3*ATEMP**2)*1.0E-6 035590
C***** 035600
RHOAIR = AOSMT*(P/PZERO)*(TZERO/T) 035610
A = TZERO/T 035620
B = AVOGAD/AMWT(1) 035630
IF(AMSMIX.LE.0.0) GO TO 110 035640
C*****GIVEN MASS MIXING RATIO (GM KG-1) 035650
DENNUM = B*AMSMIX*1.0E-3*RHOAIR 035660
GO TO 200 035670
110 CONTINUE 035680
IF(DENH20.LE.0.0) GO TO 120 035690
C*****GIVEN MASS DENSITY (GM M-3) 035700
DENNUM = S*DENH20*1.0E-6 035710
GO TO 200 035720
120 CONTINUE 035730
IF(PPH20.LE.0.0) GO TO 130 035740
C*****GIVEN WATER VAPOR PARTIAL PRESSURE (MB) 035750
DENNUM = AOSMT*(PPH20/PZERO)*(TZERO/T) 035760
GO TO 200 035770
130 CONTINUE 035780
IF(RH.LE.0.0) GO TO 140 035790
C*****GIVEN RELATIVE HUMIDITY (PERCENT) 035800
DENNUM = DENSAT(A)*(RH/100.0)/((1.0-(1.0-RH/100.0)*DENSAT(A)/ 035810
1 RHOAIR) 035820
GO TO 200 035830
140 CONTINUE 035840
C*****GIVEN DEWPOINT (DEG C) 035850
ATD = TZERO/(TZERO+TD) 035860
DENNUM = DENSAT(ATD)*(TZERO+TD)/T 035870
200 CONTINUE 035880
DENSAT = DENSAT(A) 035890
RHP = 100.0*(DENNUM/DENSAT)-((RHOAIR-DENSAT)/(RHOAIR-DENNUM)) 035900
WRITE(IPR,12) RHP 035910
12 FORMAT('+',95X,'RH = ',F10.2) 035920
IF(RHP.LE.100.0) GO TO 230 035930
WRITE(IPR,10) RHP 035940
10 FORMAT(/,' *****WARNING (FROM WATVAP): RELATIVE HUMIDITY = ', 035950
1 G10.3,' IS GREATER THAN 100 PERCENT') 035960
230 CONTINUE 035970
RETURN 035980
END 035990

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SUBROUTINE GEOINP(H1,H2,ANGLE,RANGE,BETA,ITYPE,LEN,HMIN,PHI,
1 IERROR)
C*****
C GEOINP INTERPRETS THE ALLOWABLE COMBINATIONS OF INPUT PATH
C PARAMETERS INTO THE STANDARD SET H1,H2,ANGLE,PHI,HMIN, AND LEN.
C THE ALLOWABLE COMBINATIONS OF INPUT PARAMETERS ARE- FOR ITYPE = 2,
C (SLANT PATH H1 TO H2) A. H1, H2, AND ANGLE, B. H1, ANGLE, AND
C RANGE, C. H1, H2, AND RANGE, D. H1, H2, AND BETA -
C FOR ITYPE = 3 (SLANT PATH H1 TO SPACE, H2 = ZMAX(=100 KM,M=1 TO 6)
C A. H1 AND ANGLE, B. H1 AND HMIN (INPUT AS H2).
C THE SUBROUTINE ALSO DETECTS BAD INPUT (IMPOSSIBLE GEOMETRY) AND
C ITYPE = 2 CASES WHICH INTERSECT THE EARTH, AND RETURNS THESE
C CASES WITH ERROR FLAGS.
C THE SUBROUTINE FNDHMIN IS CALLED TO CALCULATE HMIN, THE MINIMUM
C HEIGHT ALONG THE PATH, AND PHI, THE ZENITH ANGLE AT H2, USING THE
C ATMOSPHERIC PROFILE STORED IN /MDATA/
C*****
COMMON /IFIL/ IRD,IPR,IPU
COMMON /PARMT/ PI,DEG,GCAIR,RE,DELTAS,ZMIN,ZMAX,IMAX,IMOD,ISMAX,
1 IOUTMX,IPATH,IMODMX,IDIM,KDIM,KMXNOM,KMAX,NOPRNT
ITER = 0
IF(ITYPE.NE.3) GO TO 120
C*****SLANT PATH TO SPACE
C*****NOTE: IF BOTH HMIN AND ANGLE ARE ZERO, THEN ANGLE IS
C*****ASSUMED SPECIFIED
IF(H2.NE.0.0) GO TO 110
C*****CASE 3A: H1,SPACE,ANGLE
WRITE(IPR,10)
10 FORMAT(//,' CASE 3A: GIVEN H1,H2=SPACE,ANGLE')
H2 = ZMAX
CALL FNDHMIN(H1,ANGLE,H2,LEN,ITER,HMIN,PHI,IERROR)
GO TO 200
110 CONTINUE
C*****CASE 3B: H1,HMIN,SPACE
WRITE(IPR,12)
12 FORMAT(//,' CASE 3B: GIVEN H1, HMIN, H2=SPACE')
HMIN = H2
H2 = ZMAX
IF(H1.LT.HMIN) GO TO 9001
CALL FNDHMIN(HMIN,90.0,H1,LEN,ITER,HMIN,ANGLE,IERROR)
CALL FNDHMIN(HMIN,90.0,H2,LEN,ITER,HMIN,PHI,IERROR)
IF(HMIN.LT.H1) LEN = 1
GO TO 200
120 CONTINUE
IF(ITYPE.NE.2) GO TO 9002
IF(RANGE.NE.0.0.OR.BETA.NE.0.0) GO TO 130
C*****CASE 2A: H1, H2, ANGLE
WRITE(IPR,16)
16 FORMAT(//,' CASE 2A: GIVEN H1, H2, ANGLE')
IF(H1.GE.H2.AND.ANGLE.LE.90.0) GO TO 9004
IF(H1.EQ.0.0.AND.ANGLE.GT.90.0) GO TO 9007
IF(H2.LT.H1.AND.ANGLE.GT.90.0) WRITE(IPR,15) LEN
15 FORMAT(//,' EITHER A SHORT PATH (LEN=0) OR A LONG PATH ',
1 ' THROUGH A TANGENT HEIGHT (LEN=1) IS POSSIBLE: LEN = ',
2 ' )
H2ST = H2
CALL FNDHMIN(H1,ANGLE,H2,LEN,ITER,HMIN,PHI,IERROR)
IF(H2.NE.H2ST) GO TO 9007
GO TO 200
130 CONTINUE

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IF(BETA.NE.0.0) GO TO 150
IF(ANGLE.EQ.0.0) GO TO 140
C*****CASE 2B: H1, ANGLE, RANGE
C*****ASSUME NO REFRACTION
WRITE(IPR,18)
18 FORMAT(//,' CASE 2B: GIVEN H1, ANGLE, RANGE',//
1 10X,'NOTE: H2 IS COMPUTED FROM H1, ANGLE, AND RANGE ',
2 'ASSUMING NO REFRACTION')
R1 = RE+H1
R2 = SQRT(R1**2+RANGE**2+2.0*R1*RANGE*COS(+ANGLE/DEG))
H2 = R2-RE
IF(H2.GE.0.0) GO TO 135
H2 = 0.0
R2 = RE+H2
RANGE = -R1*COS(ANGLE/DEG)-SQRT(R2**2-R1**2*(SIN(ANGLE/DEG))**2)
WRITE(IPR,17) RANGE
17 FORMAT(//,10X,'CALCULATED H2 IS LESS THAN ZERO:',/,
1 10X,'RESET H2 = 0.0 AND RANGE = ',F10.3)
135 CONTINUE
C*****NOTE: GEOMETRIC PHI IS NEEDED TO DETERMINE LEN(0 OR 1).
C*****PHI IS THEN RECOMPUTED IN FNDHMN
PHI = 180.0-ACOS((R2**2+RANGE**2-R1**2)/(2.0*R2*RANGE))*DEG
LEN = 0
IF(ANGLE.GT.90.0.AND.PHI.GT.90.0) LEN = 1
CALL FNDHMN(H1,ANGLE,H2,LEN,ITER,HMIN,PHI,IERROR)
GO TO 200
140 CONTINUE
C*****CASE 2C: H1, H2, RANGE
WRITE(IPR,19)
19 FORMAT(//,' CASE 2C: GIVEN H1, H2, RANGE',//,
1 10X,'NOTE: ANGLE IS COMPUTED FROM H1, H2, AND RANGE ',
2 'ASSUMING NO REFRACTION')
IF(ABS(H1-H2).GT.RANGE) GO TO 9003
R1 = H1+RE
R2 = H2+RE
ANGLE = 180.0-ACOS((R1**2+RANGE**2-R2**2)/(2.0*R1*RANGE))*DEG
PHI = 180.0-ACOS((R2**2+RANGE**2-R1**2)/(2.0*R2*RANGE))*DEG
LEN = 0
IF(ANGLE.GT.90.0.AND.PHI.GT.90.0) LEN = 1
CALL FNDHMN(H1,ANGLE,H2,LEN,ITER,HMIN,PHI,IERROR)
GO TO 200
C*****CASE 2D: H1, H2, BETA
150 CONTINUE
CALL FDBETA(H1,H2,BETA,ANGLE,PHI,LEN,HMIN,IERROR)
GO TO 200
C*****END OF ALLOWED CASES
C*****
200 CONTINUE
C*****TEST IERROR AND RECHECK LEN
IF(IERROR.NE.0) RETURN
LEN = 0
IF(HMIN.LT.AMIN1(H1,H2)) LEN = 1
C*****REDUCE PATH ENDPOINTS ABOVE ZMAX TO ZMAX
IF(HMIN.GE.ZMAX) GO TO 9003
IF(H1.GT.ZMAX .OR. H2.GT.ZMAX) CALL REDUCE(H1,H2,ANGLE,PHI,ITER)
C*****AT THIS POINT THE FOLLOWING PARAMETERS ARE DEFINED-
C***** H1,H2,ANGLE,PHI,HMIN,LEN
WRITE(IPR,20) H1,H2,ANGLE,PHI,HMIN,LEN
20 FORMAT(//,' SLANT PATH PARAMETERS IN STANDARD FORM',//,
1 10X,'H1 = ',F10.3,' KM',/,10X,'H2 = ',F10.3,' KM',/,

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2 10X,'ANGLE = ',F10.3,' DEG',/,10X,'PHI = ',F10.3,' DEG',/,	037200
3 10X,'HMIN = ',F10.3,' KM',/,10X,'LEN = ',I10)	037210
RETURN	037220
C*****	037230
C*****ERROR MESAGES	037240
C*****	037250
9001 CONTINUE	037260
WRITE(IPR,40) H1,HMIN	037270
40 FORMAT('OGEOINP: CASE 3B (H1,HMIN,SPACE): ERROR IN INPUT DATA',	037280
1 //,10X,'H1 = ',F12.6,' IS LESS THAN HMIN = ',F12.6)	037290
GO TO 9900	037300
9002 WRITE(IPR,42) ITYPE,ITYPE	037310
42 FORMAT('OGEOINP: ERROR IN INPUT DATA, ITYPE NOT EQUAL TO ',	037320
1 ' 2, OR 3. ITYPE = ',I10,E23.14)	037330
GO TO 9900	037340
9003 WRITE(IPR,43) H1,H2,RANGE	037350
43 FORMAT('OGEOINP: CASE 2C (H1,H2,RANGE): ERROR IN INPUT DATA',/,	037360
110X,'ABS(H1-H2) GT RANGE: H1 = ',F12.6,' H2 = ',F12.6,	037370
2 ' RANGE = ',F12.6)	037380
GO TO 9900	037390
9004 CONTINUE	037400
WRITE(IPR,44) H1,H2,ANGLE	037410
44 FORMAT('OGEOINP: CASE 2A (H1,H2,ANGLE): ERROR IN INPUT DATA',	037420
1 //,10X,'H1 = ',F12.6,' IS GREATER THAN OR EQUAL TO H2 = ',	037430
2 F12.6,/,10X,'AND ANGLE = ',F12.6,' IS LESS THAN OR ',	037440
3 'EQUAL TO 90.0')	037450
GO TO 9900	037460
9007 WRITE(IPR,48)	037470
48 FORMAT('OGEOINP: ITYPE = 2: SLANT PATH INTERSECTS THE EARTH',	037480
1 ' AND CANNOT REACH H2')	037490
GO TO 9900	037500
9008 WRITE(IPR,50) ZMAX,H1,H2,HMIN	037510
50 FORMAT('GEOINP: THE ENTIRE PATH LIES ABOVE THE TOP ZMAX ',	037520
1 'OF THE ATMOSPHERIC PROFILE',/,10X,'ZMAX = ',G12.6,5X,	037530
2 ' H1 = ',G12.6,5X,' H2 = ',G12.6,' HMIN = ',G12.6)	037540
9900 IERROR = 1	037550
RETURN	037560
END	037570

	SUBROUTINE REDUCE(H1,H2,ANGLE,PHI,ITER)	037580
C.....		037590
C	ZMAX IS THE HIGHEST LEVEL IN THE ATMOSPHERIC PROFILE STORED IN	037600
C	COMMON /MDATA/. IF H1 AND/OR H2 ARE GREATER THAN ZMAX, THIS	037610
C	SUBROUTINE REDUCES THEM TO ZMAX AND RESETS ANGLE AND/OR PHI	037620
C	AS NECESSARY. THIS REDUCTION IS NECESSARY, FOR EXAMPLE FOR	037630
C	SATELLITE ALTITUDES, BECAUSE (1) THE DENSITY PROFILES ARE	037640
C	POORLY DEFINED ABOVE ZMAX AND (2) THE CALCULATION TIME FOR	037650
C	PATHS ABOVE ZMAX CAN BE EXCESSIVE (EG. FOR GEOSYNCHRONOUS	037660
C	ALTITUDES)	037670
C.....		037680
	COMMON /IFIL/ IRC,IPR,IPU	037690
	COMMON /PARMT/ PI,DEG,GCAIR,RF,DELTA,ZMIN,ZMAX,IMAX,IMOD,IBMAX,	037700
1	IOUTMX,IPATH,IMODMX,IDIM,KDIN,PMANOM,KMAX,NOPRNT	037710
	IF(H1.LE.ZMAX .AND. H2.LE.ZMAX) RETURN	037720
	CALL FINDSH(H1,SH,GAMMA)	037730
	CPATH = ANDEX(H1,SH,GAMMA)*(PI+H1)*SIN(ANGLE/180)	037740
	CALL FINDSH(ZMAX,SH,GAMMA)	037750
	CZMAX = ANDEX(ZMAX,SH,GAMMA)*(PI+ZMAX)	037760
	ANGMAX = 180.0-ASIN(CPATH/CZMAX)*180	037770
	IF(H1.LE.ZMAX,30 TO 120	037780
	H1 = ZMAX	037790
	ANGLE = ANGMAX	037800
120	CONTINUE	037810
	IF(H2.LE.'MAX') GO TO 130	037820
	H2 = ZMAX	037830
	PHI = ANGLE	037840
130	CONTINUE	037850
	IF(ITER.EQ.0) WRITE(IPR,20) ZMAX,ANGMAX	037860
20	FORMAT('////, FROM SUBROUTINE REDUCE : ',//,	037870
1	10X,'ONE OR BOTH OF H1 AND H2 ARE ABOVE THE TOP OF THE ',	037880
2	'ATMOSPHERIC PROFILE MAX = ',F10.3,' AND HAVE BEEN RESET ',	037890
3	'TO MAX.',//,10X,'ANGLE AND/OR PHI HAVE ALSO BEEN RESET TO ',	037900
4	'4' ZENITH ANGLE AT 27.7 = ',F10.3,' DEG')	037910
200	CONTINUE	037920
	RETURN	037930
	END	037940

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      SUBROUTINE FDBETA(H1,H2,BETA,ANGLE,PHI,LEN,HMIN,IERROR)
C*****
C      GIVEN H1,H2,AND BETA (THE EARTH CENTERED ANGLE) THIS SUBROUTINE
C      CALCULATES THE INITIAL ZENITH ANGLE AT H1 THROUGH AN ITERATIVE
C      PROCEEDURE
C*****
      COMMON /IFIL/ IRD,IPR,IPU
      COMMON /PARMT/ PI,DEG,GCAIR,RE,DELTAS,ZMIN,ZMAX,IMAX,IMOD,IBMAX,
1      IOUTMX,IPATH,IMODMX,IDIM,KDIM,KMXNOM,KMAX,NOPRNT
C&      DOUBLE PRECISION HMOD
      COMMON HMOD(3),ZM(50),PM(50),TM(50),RFNDXM(50),DENM(20,50)
      COMMON ZP(71),PP(71),TP(71),RFNDXP(71),SP(71),
1      PPSUM(71),TPSUM(71),RHOPSM(71),DENP(20,71),AMTP(20,71)
      COMMON Z(71),P(71),T(71),RFNDX(71),DENSTY(20,71)
      DATA TOLRNC/1.0E-4/,ITERMX/10/
      IFLAG = 0
      IF(H1.GT.H2) GO TO 100
      IORDER = 1
      HA = H1
      HB = H2
      GO TO 120
100  CONTINUE
      IORDER = -1
      HA = H2
      HB = H1
120  CONTINUE
C*****LOAD ATMOSPHERIC PROFILE INTO /MODEL/
      IMAX = IMOD
      DO 130 IM=1,IMOD
      Z(IM) = ZM(IM)
      P(IM) = PM(IM)
      T(IM) = TM(IM)
      RFNDX(IM) = RFNDXM(IM)
130  CONTINUE
C*****SET PARAMETER TO SUPPRESS CALCULATION OF AMOUNTS
      IAMTB = 2
C*****GUESS AT ANGLE, INTEGRATE TO FIND BETA, TEST FOR
C*****CONVERGENCE, AND ITERATE
C*****FIRST GUESS AT ANGLE: USE THE GEOMETRIC SOLUTION(NO REFRACTION)
      ITER = 1
      RA = RE+HA
      RB = RE+HB
      SG = SQRT(RA**2+RB**2-2.0*RA*RB*COS(BETA/DEG))
      ANGLE1 = 180.0-ACOS((RA**2+SG**2-RB**2)/(2.0*RA*SG))*DEG
      HMIN = HA
      IF(ANGLE1.GT.90.0) HMIN = RA*SIN(ANGLE1/DEG)-RE
      IF(HMIN.GE.0.0) GO TO 310
      IFLAG = 1
      HMIN = 0.0
      CALL FNDHMM(HMIN,90.0,HA,LEN,ITER,HMIN,ANGLE1,IERROR)
310  CONTINUE
      WRITE(IPR,24)
24  FORMAT(///,' CASE 2D: GIVEN H1, H2, BETA:',/,/,
1      ' ITER AROUND ANGLE UNTIL BETA CONVERGES',/,/,
2      ' ITER ANGLE',T21,'BETA',T30,'DBETA',T40,'RANGE',
3      T51,'HMIN',T61,'PHI',T70,'BENDING',/,/,
4      T10,'(DEG)',T21,'(DEG)',T30,'(DEG)',T41,'(KM)',
5      T51,'(KM)',T60,'(DEG)',T71,'(DEG)',/,/)
      LEN = 0
      IF(ANGLE1.GT.90.0) LEN = 1

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CALL FNDHMN(HA,ANGLE1,HB,LEN,ITER,HMIN,PHI,IERROR)	038550
LEN = 0	038560
IF(HMIN.LT.HA) LEN = 1	038570
CALL RFPATH(HA,HB,ANGLE1,PHI,LEN,HMIN,IAMTB,RANGE,BETA1,BENDNG)	038580
DBETA = BETA-BETA1	038590
WRITE(IPR,26) ITER,ANGLE1,BETA1,DBETA,RANGE,HMIN,PHI,BENDNG	038600
26 FORMAT(15,3F10.4,2F10.3,2F10.4)	038610
IF(IFLAG.EQ.1 .AND. BETA1.LT.BETA) GO TO 9005	038620
ITER = 2	038630
DANG = (BETA/25.0)**2	038640
IF(DANG.LT.0.001) DANG = 0.001	038650
ANGLE2 = ANGLE1-DANG	038660
IF(ANGLE2.LT.0.0) ANGLE2 = 0.0	038670
LEN = 0	038680
IF(ANGLE2.GT.90.0) LEN = 1	038690
CALL FNDHMN(HA,ANGLE2,HB,LEN,ITER,HMIN,PHI,IERROR)	038700
LEN = 0	038710
IF(HMIN.LT.HA) LEN = 1	038720
CALL RFPATH(HA,HB,ANGLE2,PHI,LEN,HMIN,IAMTB,RANGE,BETA2,BENDNG)	038730
DBETA = BETA-BETA2	038740
WRITE(IPR,26) ITER,ANGLE2,BETA2,DBETA,RANGE,HMIN,PHI,BENDNG	038750
IF(ABS(DBETA).LE.TOLRNC) GO TO 340	038760
320 CONTINUE	038770
ITER = ITER+1	038780
ANGLE3 = ANGLE2+(ANGLE2-ANGLE1)*(BETA-BETA2)/(BETA2-BETA1)	038790
LEN = 0	038800
IF(ANGLE3.GT.90.0) LEN = 1	038810
CALL FNDHMN(HA,ANGLE3,HB,LEN,ITER,HMIN,PHI,IERROR)	038820
LEN = 0	038830
IF(HMIN.LT.HA) LEN = 1	038840
CALL RFPATH(HA,HB,ANGLE3,PHI,LEN,HMIN,IAMTB,RANGE,BETA3,BENDNG)	038850
DBETA = BETA-BETA3	038860
WRITE(IPR,26) ITER,ANGLE3,BETA3,DBETA,RANGE,HMIN,PHI,BENDNG	038870
IF(BETA3.LT.BETA.AND.HMIN.LT.0.0) GO TO 9005	038880
ANGLE1 = ANGLE2	038890
ANGLE2 = ANGLE3	038900
BETA1 = BETA2	038910
BETA2 = BETA3	038920
IF(ABS(BETA-BETA3).LT.TOLRNC) GO TO 340	038930
IF(ITER.GT.ITERMX) GO TO 9006	038940
GO TO 320	038950
340 CONTINUE	038960
IF(HMIN.LT.0.0) GO TO 9005	038970
C*****CONVERGED TO A SOLUTION	038980
ANGLE = ANGLE3	038990
BETA = BETA3	039000
C*****ASSIGN ANGLE AND PHI TO PROPER H1 AND H2	039010
IF(IORDER.EQ.1) GO TO 350	039020
TEMP = PHI	039030
PHI = ANGLE	039040
ANGLE = TEMP	039050
350 CONTINUE	039060
RETURN	039070
C*****	039080
C*****ERROR MESSAGES	039090
C*****	039100
9005 CONTINUE	039110
WRITE(IPR,45)	039120
45 FORMAT('0FDBETA, CASE 2D(H1,H2,BETA): REFRACTED TANGEN' ,	039130
1 'HEIGHT IS LESS THAN ZERO-PATH INTERSECTS THE EARTH' ,	039140

2	//,10X,'BETA IS TOO LARGE FOR THIS H1 AND H2')	039150
	GO TO 9900	039160
9006	CONTINUE	039170
	WRITE(IPR,46) H1,H2,BETA,ITER,ANGLE1,BETA1,ANGLE2,BETA2,	039180
1	ANGLE3,BETA3	039190
46	FORMAT('OFDBETA, CASE 2D (H1,H2,BETA): SOLUTION DID NOT ',	039200
1	' CONVERGE',//,10X,'H1 = ',F12.6,' H2 = ',F12.6,	039210
2	' BETA = ',F12.6,' ITERATIONS = ',I4,//,	039220
3	10X,'LAST THREE ITERATIONS ',//,	039230
4	(10X,'ANGLE = ',F15.9,' BETA = ',F15.9))	039240
9900	IERROR = 1	039250
	RETURN	039260
	END	039270

SUBROUTINE EXPINT(X,X1,X2,A)	039280
C.....	039290
C THIS SUBROUTINE EXPONENTIALLY INTERPOLATES X1 AND X2 TO X BY	039300
C THE FACTOR A	039310
C.....	039320
IF(X1.EQ.0.0 .OR. X2.EQ.0.0) GO TO 100	039330
X = X1*(X2/X1)**A	039340
RETURN	039350
100 X = X1+(X2-X1)*A	039360
RETURN	039370
END	039380

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SUBROUTINE FNDHMMN(H1,ANGLE,H2,LEN,ITER,HMIN,PHI,IERRO) 039390
C***** 039400
C THIS SUBROUTINE CALCULATES THE MINIMUM ALTITUDE HMIN ALONG 039410
C THE REFRACTED PATH AND THE FINAL ZENITH ANGLE PHI. 039420
C THE PARAMETER LEN INDICATES WHETHER THE PATH GOES THROUGH 039430
C A TANGENT HEIGHT (LEN=1) OR NOT (LEN=0). IF ANGLE > 90 AND 039440
C H1 > H2, THEN LEN CAN EITHER BE 1 OR 0, AND THE CHOICE IS 039450
C LEFT TO THE USER. 039460
C THE (INDEX OF REFRACTION - 1.0) IS MODELED AS AN EXPONENTIAL 039470
C BETWEEN THE LAYER BOUNDARIES, WITH A SCALE HEIGHT SH AND AN 039480
C AMOUNT AT THE GROUND GAMMA. 039490
C CPATH IS THE REFRACTIVE CONSTANT FOR THIS PATH AND 039500
C EQUALS INDEX(H1)*(RE+H1)*SIN(ANGLE). 039510
C***** 039520
COMMON /IFIL/ IRD,IPR,IPU 039530
COMMON /PARMT/ PI,DEG,GCAIR,RE,DELTAS,ZMIN,ZMAX,IMAX,IMOD,IBMAX, 039540
1 IGUTMX,IPATH,IMODMX,IDIM,KDIM,KMXNOM,KMAX,IPRINT 039550
DATA DH/1.0/,ETA/5.0E-8/ 039560
C*****ETA MAY BE TOO SMALL FOR SOME COMPUTERS. TRY 1.0E-7 FOR 32 BIT 039570
C*****WORD MACHINES 039580
CRFRCT(H) = (RE+H)*ANDEX(H,SH,GAMMA) 039590
N = 0 039600
CALL FINDSH(H1,SH,GAMMA) 039610
CPATH = CRFRCT(H1)*SIN(ANGLE/DEG) 039620
CALL FINDSH(H2,SH,GAMMA) 039630
CH2 = CRFRCT(H2) 039640
IF(ABS(CPATH/CH2).GT.1.0) GO TO 200 039650
IF(ANGLE.GT.90.0) GO TO 100 039660
LEN = 0 039670
HMIN = H1 039680
GO TO 160 039690
100 CONTINUE 039700
IF(H1.LE.H2) LEN = 1 039710
IF(LEN.EQ.1) GO TO 110 039720
LEN = 0 039730
HMIN = H2 039740
GO TO 160 039750
110 CONTINUE 039760
C*****LONG PATH THROUGH A TANGENT HEIGHT. 039770
C*****SOLVE ITERATIVELY FOR THE TANGENT HEIGHT HT. 039780
C*****HT IS THE HEIGHT FOR WHICH INDEX(HT)*(RE+HT) = CPATH. 039790
CALL FINDSH(0.0,SH,GAMMA) 039800
CMIN = CRFRCT(0.0) 039810
C*****FOR BETA CASES (ITER>0), ALLOW FOR HT < 0.0 039820
IF(ITER.EQ.0 .AND. CPATH.LT.CMIN) GO TO 150 039830
HT1 = (RE+H1)*SIN(ANGLE/DEG)-RE 039840
CALL FINDSH(HT1,SH,GAMMA) 039850
CT1 = CRFRCT(HT1) 039860
HT2 = HT1-DH 039870
CALL FINDSH(HT2,SH,GAMMA) 039880
CT2 = CRFRCT(HT2) 039890
C*****ITERATE TO FIND HT 039900
N = 2 039910
120 CONTINUE 039920
N = N+1 039930
HT3 = HT2+(HT2-HT1)*(CPATH-CT2)/(CT2-CT1) 039940
CALL FINDSH(HT3,SH,GAMMA) 039950
CT3 = CRFRCT(HT3) 039960
DC = CPATH-CT3 039970
IF(ABS((CPATH-CT3)/CPATH).LT.ETA) GO TO 130 039980

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IF(N.GT.15) GO TO 210	039990
HT1 = HT2	040000
CT1 = CT2	040010
HT2 = HT3	040020
CT2 = CT3	040030
GO TO 120	040040
130 CONTINUE	040050
HT = HT3	040060
HMIN = HT	040070
GO TO 160	040080
150 CONTINUE	040090
C*****TANGENT PATH INTERSECTS EARTH	040100
H2 = 0.0	040110
HMIN = 0.0	040120
LEN = 0	040130
CH2 = CMIN	040140
WRITE(IPR,22) H1,ANGLE	040150
22 FORMAT(///,' TANGENT PATH WITH H1 = ',F10.3,' AND ANGLE = ',	040160
1 F10.3,' INTERSECTS THE EARTH',//,10X,'H2 HAS BEEN RESET ',	040170
2 'TO 0.0 AND LEN TO 0')	040180
160 CONTINUE	040190
C*****CALCULATE THE ZENITH ANGLE PHI AT H2	040200
PHI = ASIN(CPATH/CH2)*DEG	040210
IF(ANGLE.LE.90.0 .OR. LEN.EQ.1) PHI = 180.0-PHI	040220
RETURN	040230
C*****H2 LT TANGENT HEIGHT FOR THIS H1 AND ANGLE	040240
200 CONTINUE	040250
WRITE(IPR,20)	040260
20 FORMAT('H2 IS LESS THAN THE TANGENT HEIGHT FOR THIS PATH ',	040270
1 'AND CANNOT BE REACHED')	040280
IERROR = 2	040290
RETURN	040300
210 CONTINUE	040310
DC = CPATH-CT3	040320
WRITE(IPR,24) N,CPATH,CT3,DC,HT3	040330
24 FORMAT(///,'FROM SUBROUTINE FNDHWN :',//,	040340
1 10X,'THE PROCEEDURE TO FIND THE TANGENT HEIGHT DID NOT ',	040350
2 'CONVERG AFTER ',I3,' ITERATIONS',//,	040360
3 10X,'CPATH = ',F12.5,' KM',//,10X,'CT3 = ',F12.5,' KM',	040370
4 //,10X,'DC = ',E12.3,' KM',//,	040380
5 10X,'HT3 = ',F12.5,' KM')	040390
STOP 05	040400
END	040410

	SUBROUTINE FINDSH(H,SH,GAMMA)	040420
C*****		040430
C	GIVEN AN ALTITUDE H, THIS SUBROUTINE FINDS THE LAYER BOUNDARIES	040440
C	Z(I1) AND Z(I2) WHICH CONTAIN H, THEN CALCULATES THE SCALE	040450
C	HEIGHT (SH) AND THE VALUE AT THE GROUND (GAMMA+1) FOR THE	040460
C	REFRACTIVITY (INDEX OF REFRACTION -1)	040470
C*****		040480
	COMMON /IFIL/ IRD,IPR,IPU	040490
	COMMON /PARMTR/ PI,DEG,GCAIR,RE,DELTAS,ZMIN,ZMAX,IMAX,IMOD,IBMAX,	040500
1	IDUTMX,IPATH,IMODMX,IDIM,KDIM,KMXNOM,KMAX,NOPRNT	040510
C&	DOUBLE PRECISION HMOD	C&040520
	COMMON HMOD(2),ZM(50),PM(50),TM(50),RFNDXM(50),DENM(20,50)	040530
	COMMON ZP(71),PP(71),TP(71),RFNDXP(71),SP(71),	040540
1	PPSUM(71),TPSUM(71),RHOPSM(71),DENP(20,71),AMTP(20,71)	040550
	COMMON Z(71),P(71),T(71),RFNDX(71),DENSTY(20,71)	040560
	DO 100 IM=2,IMOD	040570
	I2 = IM	040580
	IF(ZM(IM).GE.H) GO TO 110	040590
100	CONTINUE	040600
	I2 = IMOD	040610
110	CONTINUE	040620
	I1 = I2-1	040630
	CALL SCALHT(ZM(I1),ZM(I2),RFNDXM(I1),RFNDXM(I2),SH,GAMMA)	040640
	RETURN	040650
	END	040660

SUBROUTINE SCALHT(Z1,Z2,RFNDX1,RFNDX2,SH,GAMMA)	040670
C*****	040680
C THIS SUBROUTINE CALCULATES THE SCALE HEIGHT SH OF THE (INDEX OF	040690
C REFRACTION-1.0) FROM THE VALUES OF THE INDEX AT THE ALTITUDES Z1	040700
C AND Z2 (Z1 < Z2). IT ALSO CALCULATES THE EXTRAPOLATED VALUE	040710
C GAMMA OF THE (INDEX-1.0) AT Z = 0.0	040720
C*****	040730
RF1 = RFNDX1+1.0E-20	040740
RF2 = RFNDX2+1.0E-20	040750
RATIO = RF1/RF2	040760
IF(ABS(RATIO-1.0).LT.1.0E-05) GO TO 100	040770
SH = (Z2-Z1)/ALOG(RATIO)	040780
GAMMA = RF1*(RF2/RF1)**(-Z1/(Z2-Z1))	040790
GO TO 110	040800
100 CONTINUE	040810
C*****THE VARIATION IN THE INDEX OF REFRACTION WITH HEIGHT IS	040820
C*****INSIGNIFICANT OR ZERO	040830
SH = 0.0	040840
GAMMA = RFNDX1	040850
110 CONTINUE	040860
RETURN	040870
END	040880

FUNCTION ANDEX(H,SH,GAMMA)	040890
C*****	040900
C COMPUTES THE INDEX OF REFRACTION AT HEIGHT H, SH IS THE	040910
C SCALE HEIGHT, GAMMA IS THE VALUE AT H=0 OF THE REFRACTIVITY =	040920
C INDEX-1	040930
C*****	040940
IF(SH.EQ.0.0) GO TO 10	040950
ANDEX = 1.0+GAMMA*EXP(-H/SH)	040960
RETURN	040970
10 ANDEX = 1.0+GAMMA	040980
RETURN	040990
END	041000

FUNCTION RADREF(H,SH,GAMMA)	041010
C.....	041020
C COMPUTES THE RADIUS OF CURVATURE OF THE REFRACTED RAY FOR	041030
C A HORIZONTAL PATH. RADREF = ANDEX/ D(ANDEX)/D(RADIUS)	041040
C.....	041050
DATA BIGNUM/1.0E36/	041060
IF(SH.EQ.0.0) GO TO 20	041070
RADREF = SH*(1.0+EXP(H/SH)/GAMMA)	041080
RETURN	041090
20 RADREF = BIGNUM	041100
RETURN	041110
END	041120

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SUBROUTINE RFPATH(H1,H2,ANGLE,PHI,LEN,HMIN,IAMT,RANGE,BETA,BENDNG) 041130
C***** 041140
C THIS SUBROUTINE TRACES THE REFRACTED RAY FROM H1 WITH A 041150
C INITIAL ZENITH ANGLE ANGLE TO H2 WHERE THE ZENITH ANGLE IS PHI, 041160
C AND CALCULATES THE ABSORBER AMOUNTS (IF IAMT.EQ.1) ALONG 041170
C THE PATH. IT STARTS FROM THE LOWEST POINT ALONG THE PATH 041180
C (THE TANGENT HEIGHT HMIN IF LEN = 1 OR HA = MIN(H1,H2) IF LEN = 0) 041190
C AND PROCEEDS TO THE HIGHEST POINT. BETA AND RANGE ARE THE 041200
C EARTH CENTERED ANGLE AND THE TOTAL DISTANCE RESPECTIVELY 041210
C FOR THE REFRACTED PATH FROM H1 TO H2, AND BENDNG IS THE TOTAL 041220
C BENDING ALONG THE PATH 041230
C***** 041240
COMMON /IFIL/ IRD,IPR,IPU 041250
COMMON /PARMT/ PI,DEG,GCAIR,RE,DELTAS,ZMIN,ZMAX,IMAX,IMOD,IBMAX, 041260
1 IOUTMX,IPATH,IMODMX,IDIM,KDIM,KMXNOM,KMAX,NOPRNT 041270
C& DOUBLE PRECISION HMOD C&041280
COMMON HMOD(3),ZM(50),PM(50),TM(50),RFNDXM(50),DENM(20,50) 041290
COMMON ZP(71),PP(71),TP(71),RFNDXP(71),SP(71), 041300
1 PPSUM(71),TPSUM(71),RHOPSM(71),DENP(20,71),AMTP(20,71) 041310
COMMON Z(71),P(71),T(71),RFNDX(71),DENSTY(20,71) 041320
DIMENSION HLOW(2) 041330
DATA HLOW/2HH1,2HH2/ 041340
IF(H1.GT.H2) GO TO 90 041350
IORDER = 1 041360
HA = H1 041370
HB = H2 041380
ANGLEA = ANGLE 041390
GO TO 95 041400
90 CONTINUE 041410
IORDER = -1 041420
HA = H2 041430
HB = H1 041440
ANGLEA = PHI 041450
95 CONTINUE 041460
JNEXT = 1 041470
IF(IAMT.EQ.1 .AND. NOPRNT.NE.1) WRITE(IPR,20) 041480
20 FORMAT('1CALCULATION OF THE REFRACTED PATH THROUGH THE ', 041490
1 'ATMOSPHERE',///, 041500
4 T5,'I',T14,'ALTITUDE',T30,'THETA',T38,'ORANGE',T47,'RANGE', 041510
5 T57,'DBETA',T65,'BETA',T76,'PHI',T84,'DBEND',T91,'BENDING', 041520
6 T102,'PBAR',T111,'TBAR',T119,'RHOBAR',/, 041530
7 T11,'FROM',T22,'TO',/,T11,'(KM)',T21,'(KM)',T30,'(DEG)', 041540
8 T39,'(KM)',T48,'(KM)',T57,'(DEG)',T65,'(DEG)',T75,'(DEG)', 041550
9 T84,'(DEG)',T92,'(DEG)',T102,'(MB)',T112,'(K)', 041560
1 T117,'(MOL CM-3)',/, 041570
IF(LEN.EQ.0) GO TO 100 041580
C*****LONG PATH: FILL IN THE SYMETRIC PART FROM THE TANGENT HEIGHT 041590
C*****TO HA 041600
CALL FILL(HMIN,HA,JNEXT) 041610
JHA = JNEXT 041620
100 CONTINUE 041630
C*****FILL IN THE REMAINING PATH FROM HA TO HB 041640
IF(HA.EQ.HB) GO TO 110 041650
CALL FILL(HA,HB,JNEXT) 041660
110 CONTINUE 041670
JMAX = JNEXT 041680
IPATH = JMAX 041690
C*****INTEGRATE EACH SEGMENT OF THE PATH 041700
C*****CALCULATE CPATH SEPERATELY FOR LEN = 0.1 041710
IF(LEN.EQ.1) GO TO 115 041720

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CALL FINDSH(HA,SH,GAMMA)	041730
CPATH = (RE+HA)*ANDEX(HA,SH,GAMMA)*SIN(ANGLEA/DEG)	041740
GO TO 116	041750
115 CONTINUE	041760
CALL FINDSH(HMIN,SH,GAMMA)	041770
CPATH = (RE+HMIN)*ANDEX(HMIN,SH,GAMMA)	041780
116 CONTINUE	041790
BETA = 0.0	041800
S = 0.0	041810
BENDNG = 0.0	041820
IF(LEN.EQ.0) GO TO 140	041830
C*****DO SYMETRIC PART, FROM TANGENT HEIGHT(HMIN) TO HA	041840
IHLOW = 1	041850
IF(IORDER.EQ.-1) IHLOW = 2	041860
IF(IAMT.EQ.1 .AND. NOPRNT.NE.1) WRITE(IPR,24) HLOW(IHLOW)	041870
24 FORMAT(' ',T10,'TANGENT',T20,A2,/,T10,'HEIGHT',/)	041880
SINAI = 1.0	041890
COSAI = 0.0	041900
THETA = 90.0	041910
J2 = JHA-1	041920
DO 120 J=1,J2	041930
CALL SCALHT(ZP(J),ZP(J+1),RFNDXP(J),RFNDXP(J+1),SH,GAMMA)	041940
CALL ALAYER(J,SINAI,COSAI,CPATH,SH,GAMMA,IAMT,DS,DBEND)	041950
DBEND = DBEND*DEG	041960
PHI = ASIN(SINAI)*DEG	041970
DBETA = THETA-PHI+DBEND	041980
PHI = 180.0-PHI	041990
S = S+DS	042000
BENDNG = BENDNG+DBEND	042010
BETA = BETA+DBETA	042020
IF(IAMT.NE.1) GO TO 118	042030
PBAR = PPSUM(J)/RHOPSM(J)	042040
TBAR = TPSUM(J)/RHOPSM(J)	042050
RHOBAR = RHOPSM(J)/DS	042060
IF(IAMT.EQ.1 .AND. NOPRNT.NE.1) WRITE(IPR,22) J,ZP(J),ZP(J+1),	042070
1 THETA,DS,S,DBETA,BETA,PHI,DBEND,BENDNG,PBAR,TBAR,RHOBAR	042080
22 FORMAT(' ',I4,2F10.3,10F9.3,1PE9.2)	042090
118 CONTINUE	042100
THETA = 180.0-PHI	042110
120 CONTINUE	042120
C*****DOUBLE PATH QUANTITIES FOR THE OTHER PART OF THE SYMETRIC PATH	042130
BENDNG = 2.0*BENDNG	042140
BETA = 2.0*BETA	042150
S = 2.0*S	042160
IF(IAMT.EQ.1 .AND. NOPRNT.NE.1) WRITE(IPR,26) S,BETA,BENDNG	042170
26 FORMAT('C',T10,'DOUBLE RANGE, BETA, BENDING',/,	042180
1 T10,'FOR SYMMETRIC PART OF PATH',T44,F9.3,T62,F9.3,	042190
2 T89,F9.3,/))	042200
JNEXT = JHA	042210
GO TO 150	042220
140 CONTINUE	042230
C*****SHORT PATH	042240
JNEXT = 1	042250
C*****ANGLEA IS THE ZENITH ANGLE AT HA IN DEG	042260
C*****SINAI IS SIN OF THE INCIDENCE ANGLE	042270
C*****COSAI IS CARRIED SEPERATELY TO AVOID A PRECISION PROBLEM	042280
C*****WHEN SINAI IS CLOSE TO 1.0	042290
THETA = ANGLEA	042300
IF(ANGLEA.GT.45.0) GO TO 145	042310
SINAI = SIN(ANGLEA/DEG)	042320

COSAI = -COS(ANGLEA/DEG)	042330
GO TO 150	042340
145 CONTINUE	042350
SINAI = COS((90.0-ANGLEA)/DEG)	042360
COSAI = -SIN((90.0-ANGLEA)/DEG)	042370
150 CONTINUE	042380
C*****DO PATH FROM HA TO HB	042390
IF(HA.EQ.HB) GO TO 170	042400
J1 = JNEXT	042410
J2 = JMAX-1	042420
IHLOW = 1	042430
IF(IORDER.EQ.-1) IHLOW = 2	042440
IHIGH = MOD(IHLOW,2)+1	042450
IF(IAMT.EQ.1 .AND. NOPRNT.NE.1) WRITE(IPR,28) HLOW(IHLOW),	042460
1 HLOW(IHIGH)	042470
28 FORMAT(' ',T14,A2,' TO ',A2,/,)	042480
DO 160 J=J1,J2	042490
CALL SCALHT(ZP(J),ZP(J+1),RFNDXP(J),RFNDXP(J+1),SH,GAMMA)	042500
CALL ALAYER(J,SINAI,COSAI,CPATH,SH,GAMMA,IAMT,DS,DBEND)	042510
DBEND = DBEND*DEG	042520
PHI = ASIN(SINAI)*DEG	042530
DBETA = THETA-PHI+DBEND	042540
PHI = 180.0-PHI	042550
S = S+DS	042560
BENDNG = BENDNG+DBEND	042570
BETA = BETA+DBETA	042580
IF(IAMT.NE.1) GO TO 158	042590
PBAR = PPSUM(J)/RHOPSM(J)	042600
TBAR = TPSUM(J)/RHOPSM(J)	042610
RHOBAR = RHOPSM(J)/DS	042620
IF(IAMT.EQ.1 .AND. NOPRNT.NE.1) WRITE(IPR,22) J,ZP(J),ZP(J+1),	042630
1 THETA,DS,S,DBETA,BETA,PHI,DBEND,BENDNG,PBAR,TBAR,RHOBAR	042640
158 CONTINUE	042650
THETA = 180.0-PHI	042660
160 CONTINUE	042670
170 CONTINUE	042680
IF(IORDER.EQ.-1) PHI = ANGLEA	042690
RANGE = S	042700
RETURN	042710
END	042720

SUBROUTINE FILL(HA,HB,JNEXT)	042730
C*****	042740
C THIS SUBROUTINE DEFINES THE ATMOSPHERIC BOUNDARIES OF THE PATH	042750
C FROM HA TO HB AND INTERPOLATES (EXTRAPOLATES) THE DENSITIES TO	042760
C THESE BOUNDARIES ASSUMING THE DENSITIES VARY EXPONENTIALLY	042770
C WITH HEIGHT.	042780
C*****	042790
COMMON /IFIL/ IRD,IPR,IPU	042800
COMMON /PARMTR/ PI,DEG,GCAIR,RE,DELTAS,ZMIN,ZMAX,IMAX,IMOD,IBMAX,	042810
1 IOUTMX,IPATH,IMODMX,IDIM,KDIM,KMXNOM,KMAX,NOPRNT	042820
CA DOUBLE PRECISION HMOD	042830
COMMON HMOD(3),ZM(50),PM(2),TM(50),RFNDXM(50),DENM(20,50)	042840
COMMON ZP(71),PP(71),TP(71),RFNDXP(71),SP(71),	042850
1 PPSUM(71),TPSUM(71),RHOP,SM(71),DENP(20,71),AMTP(20,71)	042860
COMMON Z(71),P(71),T(71),RFNDX(71),DENSTY(20,71)	042870
IF(HA.LT.HB) GO TO 90	042880
WRITE(IPR,22) HA,HB,JNEXT	042890
22 FORMAT('SUBROUTINE FILL- ERROR, HA .GE. HB',//,	042900
1 10X,'HA, HB, JNEXT = ',2E25.15,16)	042910
STOP 06	042920
90 CONTINUE	042930
C*****FIND Z(IA)- THE SMALLEST Z(I).GT.HA	042940
DO 100 I=1,IMAX	042950
IF(HA.GE.Z(I)) GO TO 100	042960
IA = I	042970
GO TO 110	042980
100 CONTINUE	042990
IA = IMAX+1	043000
IB = IA	043010
GO TO 130	043020
C*****FIND Z(IB)- THE SMALLEST Z(I).GE.HB	043030
110 CONTINUE	043040
DO 120 I=IA,IMAX	043050
IF(HB.GT.Z(I)) GO TO 120	043060
IB = I	043070
GO TO 130	043080
120 CONTINUE	043090
IB = IMAX+1	043100
130 CONTINUE	043110
C*****INTERPOLATE DENSITIES TO HA, HB	043120
ZP(JNEXT) = HA	043130
I2 = IA	043140
IF(I2.EQ.1) I2 = 2	043150
IF(I2.GT.IMAX) I2 = IMAX	043160
I1 = I2-1	043170
A = (HA-Z(I1))/(Z(I2)-Z(I1))	043180
CALL EXPINT(PP(JNEXT),P(I1),P(I2),A)	043190
TP(JNEXT) = T(I1)+(T(I2)-T(I1))*A	043200
CALL EXPINT(RFNDXP(JNEXT),RFNDX(I1),RFNDX(I2),A)	043210
DO 140 K=1,KMAX	043220
CALL EXPINT(DENP(K,JNEXT),DENSTY(K,I1),DENSTY(K,I2),A)	043230
140 CONTINUE	043240
IF(IA.EQ.IB) GO TO 160	043250
C*****FILL IN DENSITIES BETWEEN HA AND HB	043260
I1 = IA	043270
I2 = IB-1	043280
DO 150 I=I1,I2	043290
JNEXT = JNEXT+1	043300
ZP(JNEXT) = Z(I)	043310
PP(JNEXT) = P(I)	043320

TP(JNEXT) = T(I)	043330
RFNDXP(JNEXT) = RFNDX(I)	043340
DO 150 K=1,KMAX	043350
DENP(K,JNEXT) = DENSTY(K,I)	043360
150 CONTINUE	043370
160 CONTINUE	043380
C*****INTERPOLATE THE DENSITIES TO HB	043390
JNEXT = JNEXT+1	043400
ZP(JNEXT) = HB	043410
I2 = I8	043420
IF(I2.EQ.1) I2 = 2	043430
IF(I2.GT.IMAX) I2 = IMAX	043440
I1 = I2-1	043450
A = (HB-Z(I1))/(Z(I2)-Z(I1))	043460
CALL EXPINT(PP(JNEXT),P(I1),P(I2),A)	043470
TP(JNEXT) = T(I1)+(T(I2)-T(I1))*A	043480
CALL EXPINT(RFNDXP(JNEXT),RFNDX(I1),RFNDX(I2),A)	043490
DO 170 K=1,KMAX	043500
CALL EXPINT(DENP(K,JNEXT),DENSTY(K,I1),DENSTY(K,I2),A)	043510
170 CONTINUE	043520
RETURN	043530
END	043540


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SUBROUTINE A_LAYER(J,SINAI,COSAI,CPATH,SH,GAMMA,IAMT,S,BEND) 043550
C***** 043560
C THIS SUBROUTINE TRACES THE OPTICAL RAY THROUGH ONE LAYER FROM 043570
C Z1 TO Z2 AND IF IAMT.NE.2 CALCULATES THE INTEGRATED ABSORBER 043580
C AMOUNTS FOR THE LAYER. SINAI IS THE SIN OF THE INITIAL INCIDENCE 043590
C ANGLE (= 180 - ZENITH ANGLE). COSAI IS CARRIED SEPERATELY TO 043600
C AVOID A PRECISION PROBLEM NEAR SINAI = 1. CPATH IS THE CONSTANT 043610
C OF REFRACTION FOR THE PATH = INDEX*RADIUS*SINAI, SH AND GAMMA ARE 043620
C THE SCALE HEIGHT AND THE AMOUNT AT THE GROUND FOR THE REFRACTIVITY 043630
C (= 1-INDEX OF REFRACTION), S IS THE REFRACTED PATH LENGTH THROUGH 043640
C THE LAYER, BETA IS THE EARTH CENTERED ANGLE, AND BEND IS THE 043650
C BENDING THROUGH THE LAYER. IAMT CONTROLS WHETHER AMOUNTS ARE 043660
C CALCULATED OR NOT. 043670
C***** 043680
COMMON /IFIL/ IRD,IPR,IPU 043690
COMMON /PARMTR/ PI,DEG,GCAIR,RE,DELTAS,ZMIN,ZMAX,IMAX,IMOD,IBMAX, 043700
1 IOUTMX,IPATH,IMODMX,IDIM,KDIM,KMXNOM,KMAX,NOPRNT 043710
C& DOUBLE PRECISION HMDD C&043720
COMMON HMDD(3),ZM(50),PM(50),TM(50),RFNDXM(50),DENM(20,50) 043730
COMMON ZP(71),PP(71),TP(71),RFNDXP(71),SP(71), 043740
1 PPSUM(71),TPSUM(71),RHOPSM(71),DENP(20,71),AMTP(20,71) 043750
COMMON Z(71),P(71),T(71),RFNDX(71),DENSTY(20,71) 043760
1 DIMENSION HDEN(20),DENA(20),DENB(20) 043770
DATA EPSILN/1.0E-5/ 043780
N = 0 043790
Z1 = ZP(J) 043800
Z2 = ZP(J+1) 043810
H1 = Z1 043820
R1 = RE+H1 043830
DHMIN = DELTAS**2/(2.0*R1) 043840
SINAI1 = SINAI 043850
COSAI1 = COSAI 043860
IF((1.0-SINAI).LT.EPSILN) Y1 = COSAI1**2/2.0+COSAI1**4/8.0+ 043870
1 COSAI1**6*3.0/48.0 043880
Y2 = 0.0 043890
X1 = -R1*COSAI1 043900
RATIO1 = R1/RADREF(H1,SH,GAMMA) 043910
DSDX1 = 1.0/(1.0-RATIO1*SINAI1**2) 043920
DBNDX1 = DSDX1*SINAI1*RATIO1/R1 043930
S = 0.0 043940
BEND = 0.0 043950
IF(IAMT.EQ.2) GO TO 110 043960
C*****INITIALIZE THE VARIABLES FOR THE CALCULATION OF THE 043970
C*****ABSORBER AMOUNTS 043980
PA = PP(J) 043990
PB = PP(J+1) 044000
TA = TP(J) 044010
TB = TP(J+1) 044020
RHOA = PA/(GCAIR+TA) 044030
RHOB = PB/(GCAIR+TB) 044040
DZ = ZP(J+1)-ZP(J) 044050
HP = -DZ/ALOG(PB/PA) 044060
IF(ABS(RHOB/RHOA-1.0).LT.EPSILN) GO TO 90 044070
HRHO = -DZ/ALOG(RHOB/RHOA) 044080
GO TO 95 044090
90 HRHO = 1.0E30 044100
95 CONTINUE 044110
DO 105 K=1,KMAX 044120
DENA(K) = DENP(K,J) 044130
DENB(K) = DENP(K,J+1) 044140

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      IF(DENA(K).EQ.0.0 .OR. DENB(K).EQ.0.0) GO TO 100
      IF(ABS(1.0-DENA(K)/DENB(K)).LE.EPSLN) GO TO 100
C*****USE EXPONENTIAL INTERPOLATION
      HDEN(K, = -DZ/ALOG(DENB(K)/DENA(K))
      GO TO 105
C*****USE LINEAR INTERPOLATION
      100 HDEN(K) = 0.0
      105 CONTINUE
      110 CONTINUE
C*****
C*****LOOP THROUGH PATH
C*****INTEGRATE PATH QUANTITIES USING QUADRATIC INTEGRATION WITH
C*****UNEQUALLY SPACED POINTS
C*****
      115 CONTINUE
      N = N+1
      DH = -DELTA*COA11
      IF(DH.LT.DHMIN) DH = DHMIN
      H3 = H1+DH
      IF(H3.GT.Z2) H3 = Z2
      DH = H3-H1
      R3 = RE+H3
      H2 = H1+DH/2.0
      R2 = RE+H2
      SINAI2 = CPATH/(ANDEX(H2,SH,GAMMA)*R2)
      SINAI3 = CPATH/(ANDEX(H3,SH,GAMMA)*R3)
      RATIO2 = R2/RADREF(H2,SH,GAMMA)
      RATIO3 = R3/RADREF(H3,SH,GAMMA)
      IF((1.0-SINAI2).GT.EPSLN) GO TO 116
C*****NEAR A TANGENT HEIGHT, COA1 = -SQRT(1-SINAI**2) LOSES
C*****PRECISION. USE THE FOLLOWING ALGORITHM TO GET COA1.
      Y3 = Y1+(SINAI1*(1.0-RATIO1)/R1+4.0*SINAI2*(1.0-RATIO2)/R2+
1      SINAI3*(1.0-RATIO3)/R3)*DH/6.0
      COA13 = -SQRT(2.0*Y3-Y3**2)
      X3 = -R3*COA13
      DX = X3-X1
      W1 = 0.5*DX
      W2 = 0.0
      W = 0.5*DX
      GO TO 118
C*****
      116 CONTINUE
      COA12 = -SQRT(1.0-SINAI2**2)
      COA13 = -SQRT(1.0-SINAI3**2)
      X2 = -R2*COA12
      X3 = -R3*COA13
C*****CALCULATE WEIGHTS
      D31 = X3-X1
      D32 = X3-X2
      D21 = X2-X1
      IF(D32.EQ.0.0 .OR. D21.EQ.0.0) GO TO 117
      W1 = (2.0-D32/D21)*D31/6.0
      W2 = D31**3/(D32*D21*6.0)
      W3 = (2.0-D21/D32)*D31/6.0
      GO TO 118
      117 CONTINUE
      W1 = 0.5*D31
      W2 = 0.0
      W3 = 0.5*D31
C*****

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118 CONTINUE	044750
DSDX2 = 1.0/(1.0-RATIO2*SINA12**2)	044760
DSDX3 = 1.0/(1.0-RATIO3*SINA13**2)	044770
DBNDX2 = DSDX2*SINA12*RATIO2/R2	044780
DBNDX3 = DSDX3*SINA13*RATIO3/R3	044790
C*****INTEGRATE	044800
DS = W1*DSDX1+W2*DSDX2+W3*DSDX3	044810
S = S+DS	044820
DBEND = W1*DBNDX1+W2*DBNDX2+W3*DBNDX3	044830
BEND = BEND+DBEND	044840
IF(IAMT.EQ.2) GO TO 150	044850
C*****CALCULATE AMOUNTS	044860
DSDZ = DS/DH	044870
PB = PA*EXP(-DH/HP)	044880
RHOB = RHOA*EXP(-DH/HRHO)	044890
IF((DH/HRHO).LT.EPSILN) GO TO 120	044900
PPSUM(J) = PPSUM(J)+DSDZ*(HP/(1.0+HP/HRHO))*(PA*RHOA-PB*RHOB)	044910
TPSUM(J) = TPSUM(J)+DSDZ*HP*(PA-PB)/GCAIR	044920
RHOPSM(J) = RHOPSM(J)+DSDZ*HRHO*(RHOA-RHOB)	044930
GO TO 125	044940
120 CONTINUE	044950
PPSUM(J) = PPSUM(J)+0.5*DS*(PA*RHOA+PB*RHOB)	044960
TPSUM(J) = TPSUM(J)+0.5*DS*(PA+PB)/GCAIR	044970
RHOPSM(J) = RHOPSM(J)+0.5*DS*(RHOA+RHOB)	044980
125 CONTINUE	044990
DO 140 K=1,KMAX	045000
IF(HDEN(K).EQ.0.0) GO TO 130	045010
IF(ABS(DH/HDEN(K)).LT.EPSILN) GO TO 130	045020
C*****EXPONENTIAL INTERPOLATION	045030
DENB(K) = DENP(K,J)*EXP(-(H3-Z1)/HDEN(K))	045040
C*****1.0E5 FACTOR CONVERTS FROM KM TO CM	045050
AMTP(K,J) = AMTP(K,J)+DSDZ*HDEN(K)*(DENA(K)-DENB(K))*1.0E5	045060
GO TO 140	045070
130 CONTINUE	045080
C*****LINEAR INTERPOLATION	045090
DENB(K) = DENP(K,J)+(DENP(K,J+1)-DENP(K,J))*(H3-Z1)/DZ	045100
AMTP(K,J) = AMTP(K,J)+0.5*(DENA(K)+DENB(K))*DS*1.0E5	045110
140 CONTINUE	045120
PA = PB	045130
RHOA = RHOB	045140
DO 145 K=1,KMAX	045150
145 DENA(K) = DENB(K)	045160
150 CONTINUE	045170
IF(H3.GE.Z2) GO TO 160	045180
H1 = H3	045190
R1 = R3	045200
SINA11 = SINA13	045210
RATIO1 = RATIO3	045220
Y1 = Y3	045230
COSA11 = COSA13	045240
X1 = X3	045250
DSOX1 = DSDX3	045260
DBNDX1 = DBNDX3	045270
CG TO 115	045280
160 CONTINUE	045290
SINA1 = SINA13	045300
COSA1 = COSA13	045310
SP(J) = S	045320
RETURN	045330
END	045340

```

SUBROUTINE AUTLAY(HMIN,HMAX,VBAR,AVTRAT,TDIFF1,TDIFF2,IBND,
1 ERROR)
C*****
C THIS SUBROUTINE AUTOMATICALLY SELECTS A SET OF FASCODE BOUNDARY
C LEVELS WHICH SATISFY THE FOLLOWING TWO TESTS:
C 1. THE RATIO OF THE VOIGT HALFWIDTHS BETWEEN BOUNDARIES
C IS LESS THAN OR EQUAL TO AVTRAT, AND
C 2. THE TEMPERATURE DIFFERENCE BETWEEN BOUNDARIES IS
C LESS THAN OR EQUAL TO TDIFF
C TDIFF VARIES FROM TDIFF1 AT HMIN TO TDIFF2 AT HMAX,
C WITH EXPONENTIAL INTERPOLATION BETWEEN
C THESE BOUNDARIES ARE ROUNDED DOWN TO THE NEAREST TENTH KM
C NOTE THAT THESE TESTS APPLY TO THE LAYER BOUNDARIES
C NOT TO THE AVERAGE VALUES FROM ONE LAYER TO THE NEXT.
C*****
COMMON /IFIL/ IRD,IPR,IPU
COMMON /PARMT/ PI,DEG,GCAIR,RE,DELTAS,ZMIN,ZMAX,IMAX,IMOD,IBMAX,
1 IOUTMX,IPATH,IMODMX,IDIM,KDIM,KMXNOM,KMAX,NOPRNT
COMMON /CONSTN/ PZERO,TZERO,AVOGAD,ALOSMT,GASCON,PLANK,BOLTZ,
1 CLIGHT,ADCON,ALZERO,AVMWT,AIRMWT,AMWT(20),VMIXST(20),VMIXN2
C& DOUBLE PRECISION HMOD C&045550
COMMON HMOD(3),ZM(50),PM(50),TM(50),RFNDXM(50),DENM(20,50)
COMMON ZP(71),PP(71),TP(71),RFNDXP(71),SP(71),
1 PPSUM(71),TPSUM(71),RHOPSM(71),DENP(20,71),AMTP(20,71)
COMMON Z(71),P(71),T(71),RFNDX(71),DENSTY(20,71)
COMMON /BNDRY/ ZBND(34),PBND(34),TBND(34),ALORNZ(34),ADOPP(34),
1 AVOIGT(34)
DIMENSION AVTM(50)
C*****FUNCTION ZROUND ROUNDS THE ALTITUDE Z DOWN TO THE
C*****NEAREST TENTH KM
ZROUND(ZX) = 0.1*FLOAT(IFIX(10.0*ZX))
C*****
DO 100 IM=2,IMOD
IHMIN = IM
IF(ZM(IM).GT.HMIN) GO TO 120
100 CONTINUE
120 CONTINUE
HTOP = HMAX
IF(HTOP.GT.ZMAX) HTOP = ZMAX
IM = IHMIN-1
ZZ = ZM(IM)
CALL HALFWD(ZZ,VBAR,P,T,AL,AD,AVTM(IM))
IB = 1
ZBND(IB) = HMIN
IM = IHMIN
CALL HALFWD(ZBND(IB),VBAR,PBND(IB),TBND(IB),ALORNZ(IB),
1 ADOPP(IB),AVOIGT(IB))
IB = 2
C*****BEGIN LOOP
200 CONTINUE
IPASS = 0
ZBND(IB) = ZM(IM)
IF(ZBND(IB).GE.HTOP) ZBND(IB) = HTOP
CALL HALFWD(ZBND(IB),VBAR,PBND(IB),TBND(IB),ALORNZ(IB),
1 ADOPP(IB),AVOIGT(IB))
AVTM(IM) = AVOIGT(IB)
C*****TEST THE RATIO OF THE VOIGT WIDTHS AGAINST AVTRAT
IF((AVOIGT(IB-1)/AVOIGT(IB)).LT.AVTRAT) GO TO 220
C*****ZM(IM) FAILS THE HALFWIDTH RATIO TEST
IPASS = 1

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```

      AVOIGT(IB) = AVOIGT(IB-1)/AVTRAT
      ZBND(IB) = ZM(IM-1)+(ZM(IM)-ZM(IM-1))*ALOG(AVOIGT(IB)/AVTM(IM-1))/
1      ALOG(AVTM(IM)/AVTM(IM-1))
      IF(ZBND(IB).NE.HTOP) ZBND(IB) = ZROUND(ZBND(IB))
      CALL HALFWD(ZBND(IB),VBAR,PBND(IB),TBND(IB),ALORNZ(IB),
1      ADOPP(IB),AVOIGT(IB))
220 CONTINUE
C*****TEST THE TEMPERATURE DIFFERENCE AGAINST TDIFF
      FAC = (ZBND(IB-1)-HMIN)/(HMAX-HMIN)
      CALL EXPINT(TDIFF,TDIFF1,TDIFF2,FAC)
      IF(ABS(TBND(IB)-TBND(IB-1)).LE.TDIFF) GO TO 230
C*****ZBND(IB) FAILS THE TEMPERATURE DIFFERENCE TEST
      IPASS = 2
      TBND(IB) = TBND(IB-1)+SIGN(TDIFF,TM(IM)-TM(IM-1))
      ZBND(IB) = ZM(IM-1)+(ZM(IM)-ZM(IM-1))*
1      (TBND(IB)-TM(IM-1))/(TM(IM)-TM(IM-1))
      IF(ZBND(IB).NE.HTOP) ZBND(IB) = ZROUND(ZBND(IB))
      CALL HALFWD(ZBND(IB),VBAR,PBND(IB),TBND(IB),ALORNZ(IB),
1      ADOPP(IB),AVOIGT(IB))
230 CONTINUE
      IF(ZBND(IB).GE.HTOP) GO TO 300
      IF(IPASS.NE.0) GO TO 240
C*****BOTH HALFWIDTH AND TEMPERATURE TEST PASS FOR ZBND(IB) = ZM(IM),
C*****NOW TRY ZBND(IB) = ZM(IM+1)
      IM = IM+1
      GO TO 200
240 CONTINUE
C*****ONE OF THE TESTS FAILED AND A NEW BOUNDARY ZBND WAS PRODUCED
C*****TEST FOR THE NEXT BOUNDARY AT THE PREVIOUS ZM(IM)
      IB = IB+1
      IF(IB.GT.IBMAX) GO TO 900
      GO TO 200
300 CONTINUE
      IBND = IB
      WRITE(IPR,10) AVTRAT,TDIFF1,TDIFF2
10 FORMAT(///,' FASCODE LAYER BOUNDARIES PRODUCED BY THE AUTOMATIC ',
1      ' LAYERING ROUTINE AUTLAY',/, ' THE USER SHOULD EXAMINE ',
2      ' THESE BOUNDARIES AND MODIFY THEM IF APPROPRIATE',/,
3      ' THE FOLLOWING PARAMETERS ARE USED:',/,
4      10X,'AVTRAT' = ',F8.2,' = MAX RATIO OF VOIGT WIDTHS',/,
5      10X,'TDIFF1' = ',F8.2,' = MAX TEMP DIFF AT HMIN',/,
6      10X,'TDIFF2' = ',F8.2,' = MAX TEMP DIFF AT HMAX')
      RETURN
900 CONTINUE
      WRITE(IPR,901) IBMAX
901 FORMAT(///,' ERROR IN AUTLAY:',/,5X,'THE NUMBER OF ',
1      ' GENERATED LAYER BOUNDARIES EXCEEDS THE DIMENSION IBMAX ',
2      ' OF THE ARRAY ZBND. IBMAX = ',15/,
3      5X,'PROBABLE CAUSE: EITHER AVTRAT AND/OR TDIFF ARE TOO SMALL',
4      /,5X,'THE GENERATED LAYERS FOLLOW')
      IBND = IBMAX
      IERROR = 5
      RETURN
      END

```

```

SUBROUTINE HALFWD(Z,VBAR,P,T,ALORNZ,ADOPP,AVOIGT)
C*****
C      GIVEN AN ALTITUDE Z AND AN AVERAGE WAVENUMBER VBAR, THIS
C      SUBROUTINE INTERPOLATES P AND T FROM THE PROFILE IN ZM AND
C      CALCULATES THE LORENTZ, THE DOPPLER, AND THE VOIGT HALFWIDTHS
C      (AT HALFHEIGHT) ALORNZ, ADOPP, AND AVOIGT RESPECTIVELY FOR
C      THE ALTITUDE Z
C      AN AVERAGE LORENTZ WIDTH ALZERO AND AN AVERAGE MOLECULAR
C      WEIGHT AVMW ARE ASSUMED
C*****
COMMON /IFIL/ IRD,IPR,IPU
COMMON /PARMTR/ PI,DEG,GCAIR,RE,DELTAS,ZMIN,ZMAX,IMAX,IMOD,IBMAX,
1  IOUTMX,IPATH,IMODMX,IDIM,KDIM,KMXNOM,KMAX,NOPRNT
COMMON /CONSTN/ PZERO,TZERO,AVOGAD,ALOSMT,GASCON,PLANK,BOLTZ,
1  CLIGHT,ADCON,ALZERO,AVMW,AIMWT,AMWT(20),VMIXST(20),VMIXN2
C& DOUBLE PRECISION HMOD
COMMON HMOD(3),ZM(50),PM(50),TM(50),RFNDXM(50),DENM(20,50)
COMMON ZP(71),PP(71),TP(71),RFNDXP(71),SP(71),
1  PPSUM(71),TPSUM(71),RHOPSM(71),DENP(20,71),AMTP(20,71)
COMMON ZX(71),PX(71),TX(71),RFNDX(71),DENSITY(20,71)
C*****FUNCTIONS
C*****ALZERO IS AT 1013.25 MB AND 296.0 K
ALPHAL(P,T) = ALZERO*(P/PZERO)*SQRT(296.0/T)
ALPHAD(T,V) = ADCON*V*SQRT(T/AVMW)
ALPHAV(AL,AD) = 0.5*(AL+SQRT(AL**2+4.0*AD**2))
C*****
DO 100 I2=2,IMOD
IM = I2
IF(ZM(IM).GE.Z) GO TO 110
100 CONTINUE
IM = IMOD
110 CONTINUE
FAC = (Z-ZM(IM-1))/(ZM(IM)-ZM(IM-1))
CALL EXPINT(P,PM(IM-1),PM(IM),FAC)
T = TM(IM-1)+(TM(IM)-TM(IM-1))*FAC
ALORNZ = ALPHAL(P,T)
ADOPP = ALPHAD(T,VBAR)
AVOIGT = ALPHAV(ALORNZ,ADOPP)
RETURN
END

```

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Profiles From 0 to 50 km, NASA TM-83289.

Appendix A

Atmospheric Profiles

Six atmospheric profiles are included in FSCATM as a convenience to the user. These profiles consist of the pressure and temperature, and the number densities of H_2O , CO_2 , O_3 , N_2O , CO , CH_4 , and O_2 , vs altitude at 1-km steps from 0 to 25 km, 5-km steps from 25 to 50 km, and at 70 and 100 km. These profiles, taken from McClatchey et al.^{A1} correspond to the 1962 U.S. Standard Atmosphere^{A2} and five supplementary models:^{A3} Tropical (15°N), Midlatitude Summer (45°N , July), Midlatitude Winter (45° , Jan), Subarctic Summer (60°N , July), and Subarctic Winter (60°N , Jan). These profiles are identical to the ones contained in LOWTRAN.^{A4} The water vapor and ozone altitude profiles added to the 1962 U.S. Standard Atmosphere by McClatchey et al.^{A1} were obtained from Sissenwine et al.^{A5} and Hering et al.^{A6} respectively, and correspond to mean annual values. The water vapor densities for the 1962 U.S. Standard Atmosphere correspond to relative humidities of approximately 50 percent for altitudes up to 10 km, whereas the relative humidity values for the other supplementary models tend to decrease with altitude from approximately 80 percent at sea level to approximately 30 percent at 10-km altitude. Above 12 km, the water-vapor number densities of models 1 to 5 are identical and represent volume mixing ratios that reach a minimum of about 6.5 ppmv at 17 km, increase to 30 ppmv at 30 km, and then decrease to 10 ppmv at 50 km. For all models, the gases CO_2 , N_2O , CO , CH_4 , and O_2

Because of the large number of references cited above, they will not be listed here. See References, page 139.

are considered uniformly mixed with volume mixing ratios of 330, 0.28, 0.075, 1.6, and 2.095×10^5 ppm respectively.

The temperature profiles as a function of altitude for the six atmospheric models are shown in Figure A1. Figure A2 shows the water-vapor density vs altitude for 0 to 100 km and an expanded profile from 0 to 30 km. Figure A3 shows similar profiles for ozone.

In the almost 20 years since these profiles were constructed, our knowledge of the state of the atmosphere has increased enormously. This is particularly true regarding the stratosphere and above, and the concentration of minor constituents. For example, the stratospheric water-vapor concentrations for the six profiles given here are now known to be too large by a factor of 5 at 30 km. Models 1 through 6 may still be considered representative of their respective conditions up to about 50 km for temperature, up to 30 km for ozone densities, and up to the tropopause (~15 km in the Tropics to 8 km in the Arctic) for water vapor. Users may still use these models for cases dominated by the conditions in the troposphere. For cases dominated by stratospheric conditions or where the distribution of minor constituents is significant, the user should supply his own profile read in under the MODEL = 7 option.

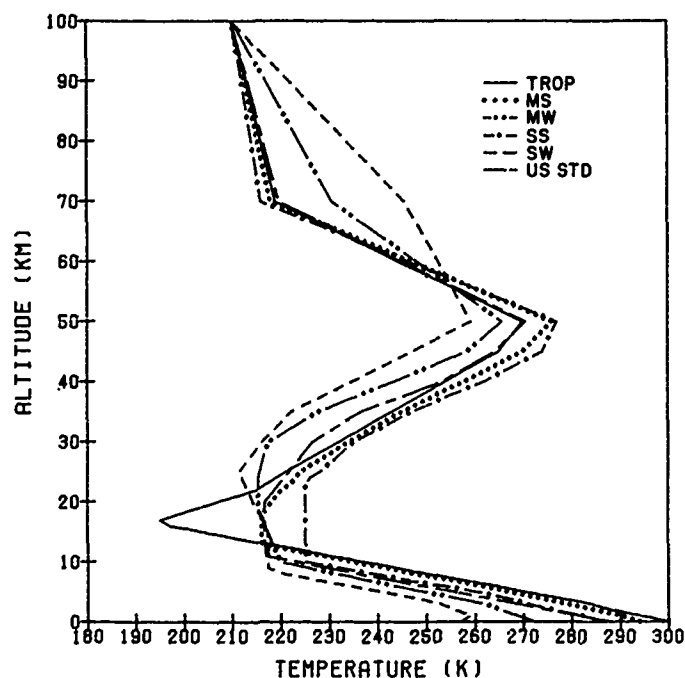


Figure A1. Temperature vs Altitude for the Six Model Atmospheres

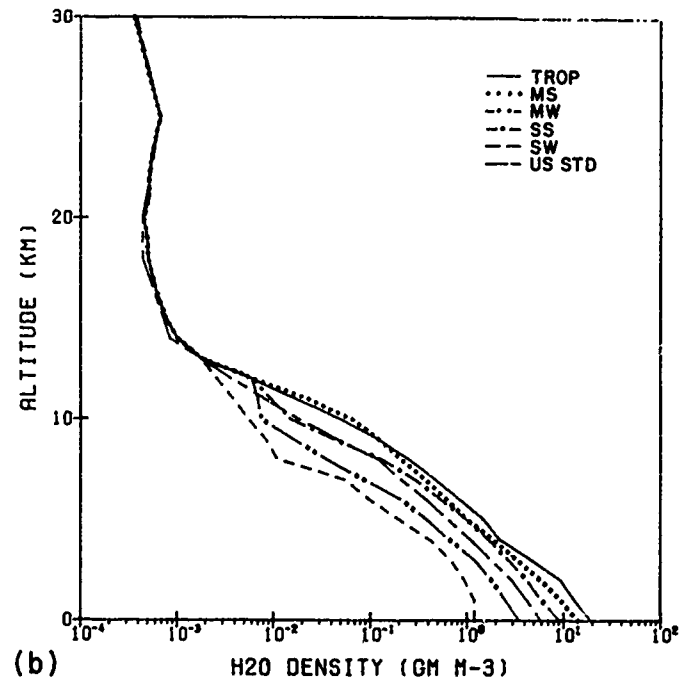
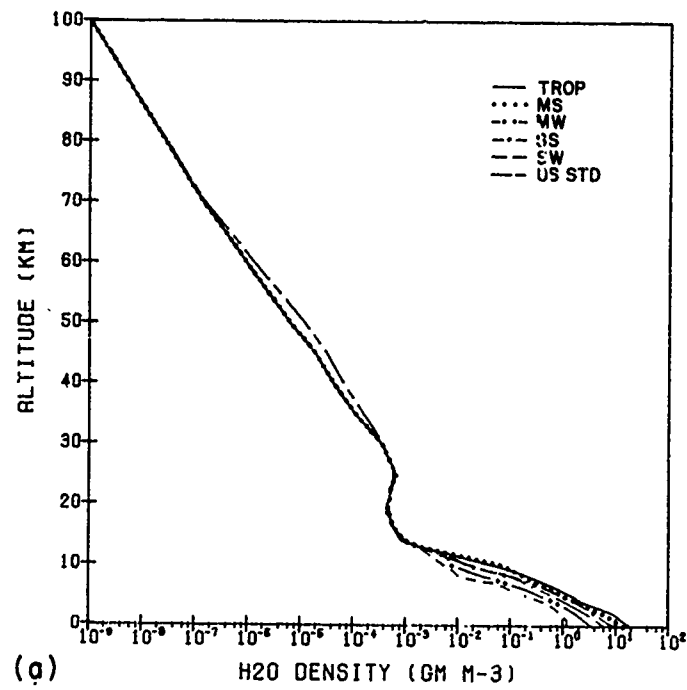


Figure A2. Water Vapor Density Profiles vs Altitude for the Six Model Atmospheres:
(a) From 0 to 100 km and (b) From 0 to 30 km

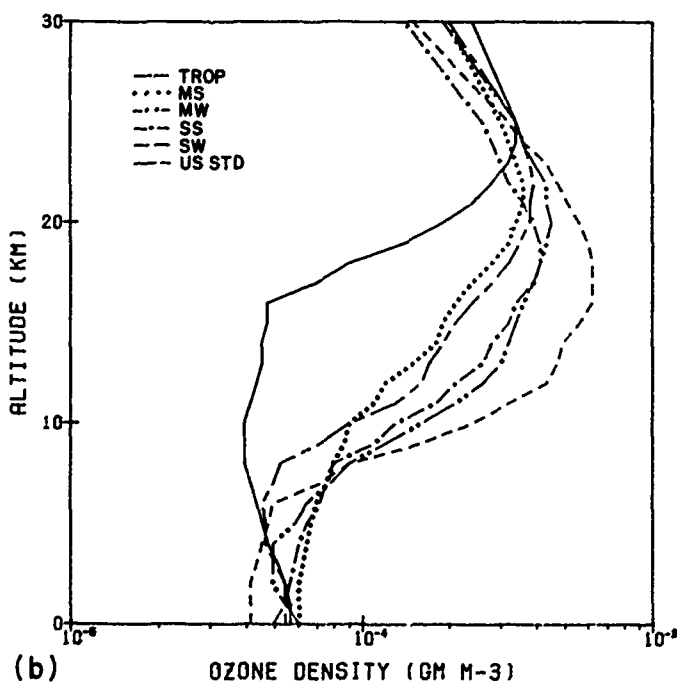
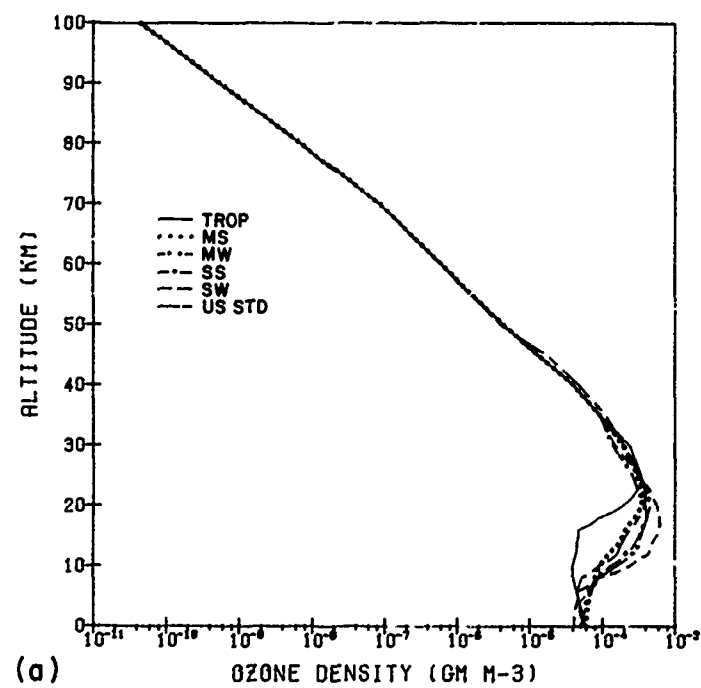


Figure A3. Ozone Profile vs Altitude for the Six Model Atmospheres: (a) From 0 to 100 km and (b) From 0 to 30 km

There are several recent sources for profiles of temperature and minor constituent density. The U.S. Standard Atmosphere 1976^{A7} updates the 1962 U.S. Standard Atmosphere for temperature above 50 km and provides revised estimates for the surface concentrations of what was termed previously "uniformly mixed gases". The new values for the volume mixing ratios of CO₂, N₂O, CO, and CH₄ are 322, 0.27, 0.19, and 1.50 ppmv respectively. These values are used as the default mixing ratios for MODEL = 7 if the user-supplied values are zero. Actually the concentration of these gases do show significant variations from these values, particularly with altitude in the stratosphere.

Cole and Kantor^{A8} provide sets of monthly mean temperature profiles up to 90 km at 15° intervals between the Equator and the pole. Along with statistics on the variability of these profiles, they also provide models that portray the longitudinal variations in monthly mean values of temperature during winter months and the vertical variation which occurs during stratospheric warming and cooling events in the winter arctic and subarctic. Houghton^{A9} provides seasonal profile temperature at 10°N, 40°N and 70°N up to 105 km plus the original references for the data (this by the way is a marvelous little book that I strongly recommend as both an introduction and a refresher in atmospheric physics).

For profiles of the minor constituents including ozone and stratosphere water vapor, Hudson et al^{A10} provides an up-to-date (June 1981) and exhaustive source. This volume is available from

Stratospheric Chemistry and Physics Branch
Code 963
NASA Goddard Space Flight Center
Greenbelt, MD 20771

or

World Meteorological Center
Case Postule No. 5
Geneva 20, Switzerland

Much of the profile data from this source plus some more recent measurements have been compiled as annual averages in 2 km steps in Smith,^{A11}

Finally a new edition of the Handbook of Geophysics^{A12} is in preparation, which will include seasonal profiles of temperature, water vapor, and ozone plus a wealth of other data. This volume should be available in 1984.

Because of the large number of references cited above, they will not be listed here. See References, page 139.

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Appendix B

Index of Refraction

The expression for the index of refraction of air is:

$$n - 1 = 10^{-6} \times (77.46 + 0.479 \times 10^{-8} * \tilde{\nu}^2) \times \frac{P}{T} \\ - \frac{P_{H_2O}}{P_o} * (43.49 - 0.347 \times 10^{-8} \tilde{\nu}^2)$$

where $\tilde{\nu}$ is the wavenumber, c is the speed of light, P and T the pressure and temperature, P_{H_2O} is the water-vapor partial pressure, and P_o is 1013.25 mb.

This expression is the same as is in the program LOWTRAN^{B1} and is a simplified version of the expression by Edlen.^{B2} For further references on the index of refraction of air, the reader is referred to References B3 and B4.

-
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Appendix C.

A Brief Survey of the Literature

The subject of air mass calculation and the associated subject of astronomical refraction go back to Laplace and have generated a large body of literature. This brief survey is meant only to point out a few references to which the interested reader can turn to for further references.

The theory of atmospheric refraction and of air mass calculation is discussed in some detail in Kondratyev, K. (1969) Radiation in the Atmosphere, Academic Press, New York, Chapter 4 and in Zuev, V. E. (1982) Laser Beams in the Atmosphere, Consultants Bureau, New York, Chapter 1.

The following paper has a fairly extensive list of references on the calculation of air mass along with graphs showing the effect of neglecting refraction for occultation geometries: Sneider, D. (1975) Refractive effects in remote sounding of the atmosphere with infrared transmission spectroscopy, J. Atmos. Sci. 32: 2178-2184.

Essentially the same paper but with tables of air mass for observer altitudes ranging from 10 to 50 km in steps of 1 km, with zenith angles ranging from 80° to 97° is Sneider, D. E., and Goldman, A. (1974) Refractive Effects in Remote Sensing of the Atmosphere With Infrared Transmission Spectroscopy, Ballistic Res. Labs, Report 1790, Aberdeen Md, DTIC No. AD-A011253.

A more recent paper with references is Wang, P. -H., Deepak, A., and Hong, S. -S. (1981) General formulation of optical paths for large zenith angles in the earth's curved atmosphere, J. Atmos. Sci. 38:650-658.

One of the earliest tabulations of air mass was by Bemporad and is reprinted in List, R.J. (1968) Smithsonian Meteorological Tables (6th Revised Edition), Smithsonian Institute Press, Washington.

In the case where refraction can be neglected and where the density profile is exponential, the air mass can be calculated analytically using the "Chapman function". The original reference is Chapman, S. (1931) The absorption and dissociative or ionizing effect of monochromatic radiation in an atmosphere on a rotating earth II. Grazing incidence, Proc. Phys. Soc. (London) 43:483-501.

Since then numerous simplifications and approximations to the Chapman functions have appeared. Among them are: (1) Fitzmaurice, J. A. (1964) Simplification of the Chapman function for atmospheric attenuation, Appl. Opt. 3:640; (2) Swider, W., Jr., and Gardner, M. E. (1967) On the Accuracy of Certain Approximations to the Chapman Functions, AFCRL-67-0468, AD 658826; (3) Swider, W., Jr., and Gardner, M. E. (1969) On the accuracy of Chapman function approximations, Appl. Opt. 3:1725; and (4) Smith, F. L. III, and Smith, C. (1972) Numerical evaluation of Chapman's grazing incidence integral, $Ch(x, \psi)$, J. Geophys. Res. 77:3592-3597.

An analytic approximation to the calculation of air mass that includes the effect of earth's curvature and refraction is in Uplinger, W.G. (1981) A Simple Model for Relative Air Mass, in preprint volume for the Fourth Conference on Atmospheric Radiation, June 1981, Toronto, Canada (American Meteorological Society).

The case in which the density scale height varies with altitude (that is, temperature) is discussed in Swider, W., Jr. (1964) The determination of the optical depth at large solar zenith distances, Planet Space Sci. 12:761-782.

Another method for dealing with non-exponential density distributions is found in Green, A. E. S., and Martin, J. D. (1966) A generalized Chapman Function, The Middle Ultraviolet: Its Science and Technology, A. E. S. Green, Ed., Wiley, New York, pp 140-157.

The following paper applies the Chapman function to a solar occultation measurement of the absorption by trace gases in the stratosphere: Menzies, R. J., Rutledge, C. W., Zanteson, R. A., and Spears, D. L. (1981) Balloonborne laser heterodyne radiometer for measurements of stratospheric trace species, Appl. Opt. 20:536-544.

Astronomical refraction refers to the bending of a ray along a path from an observer to a very distant source outside the atmosphere, for instance a star. The effect was recognized in ancient times and is still the subject of active investigation among astronomers. The following paper gives a review of the subject plus an extensive list of references: Mahan, A. I. (1962) Astronomical refraction - some history and theories, Appl. Opt. 4:497-511.

The following report gives an even more complete derivation of the mathematics of refraction plus extensive references covering refraction of visible, IR, and radio waves: Meyer-Arendt, J.R., and Emmanuel, C.B. (1965) Optical Scintillation, a Survey of the Literature, National Bureau of Standards Tech Note 225.

Analyt.. solutions for astronomical refraction for several vertical distributions of the refractive index are given in White, R. (1975) New solutions to the refraction integral, J. Opt. Soc. Am. 65:676-678.

Terrestrial refraction applies to cases in which the whole path lies near the surface of the earth and is of importance in geodesy and surveying. A recent volume devoted to both astronomical and terrestrial refraction is Tengstrom, E., and Teliki, R., Ed. (1979) Refractional Influences in Astronomy and Geodesy, IAU Symposium No. 89, D. Reidel Publishing Co., Holland.

The following report describes an atmospheric ray tracing computer program capable of handling complex problems such as mirages and ducting, for frequencies from the microwave to the visible: Able, M., Mill, J.D., and Lenn, L. (1982) The Theory and Use of a Raytracing Model Developed at USAFETAC., USAFETAC-TN-82-002.

Since this report went to press, the following two papers have come to my attention: Thompson, D.A., Pepin, T.J., and Simon, F.W. (1982) Ray tracing in a spherically symmetric atmosphere, J. Opt. Soc. 72:1498-1501 and Chu, W.P. (1983) Calculation of atmospheric refraction for spacecraft remote-sensing applications, Appl. Opt. 22:721-725.